September 2000

Vol. 24 No. 9

TECH BRIEFS

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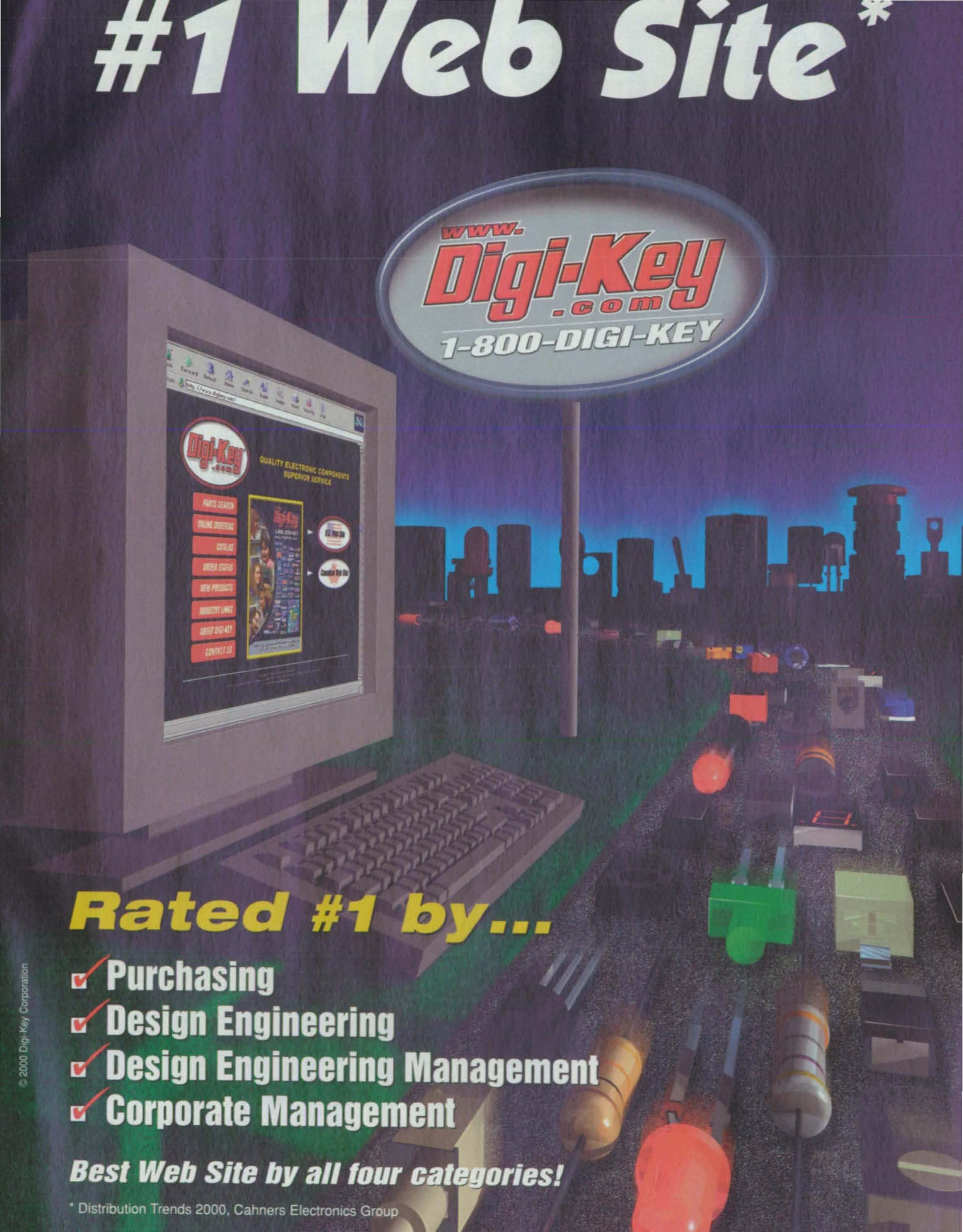

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TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING

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Version 5 Release 4 of CATIA CAD/CAM/CAE software from IBM, Dallas, TX, offers a range of built-in e-business solutions, including 12 new products.

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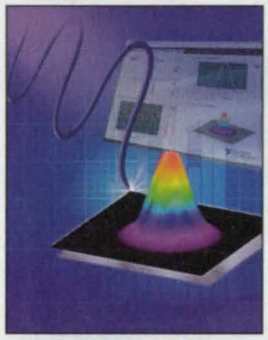
ON THE COVER



LabVIEW™ 6i is the latest version of the graphical programming language for data acquisition and analysis from National Instruments, Austin, TX. The software lets users build on-screen "virtual instruments," and stream LabVIEW-generated data across the Web. Our software reviewer, Steve Ross, provides a detailed analysis of the new version's enhanced features in the InReview column on page 24.

(Image courtesy of National Instruments)

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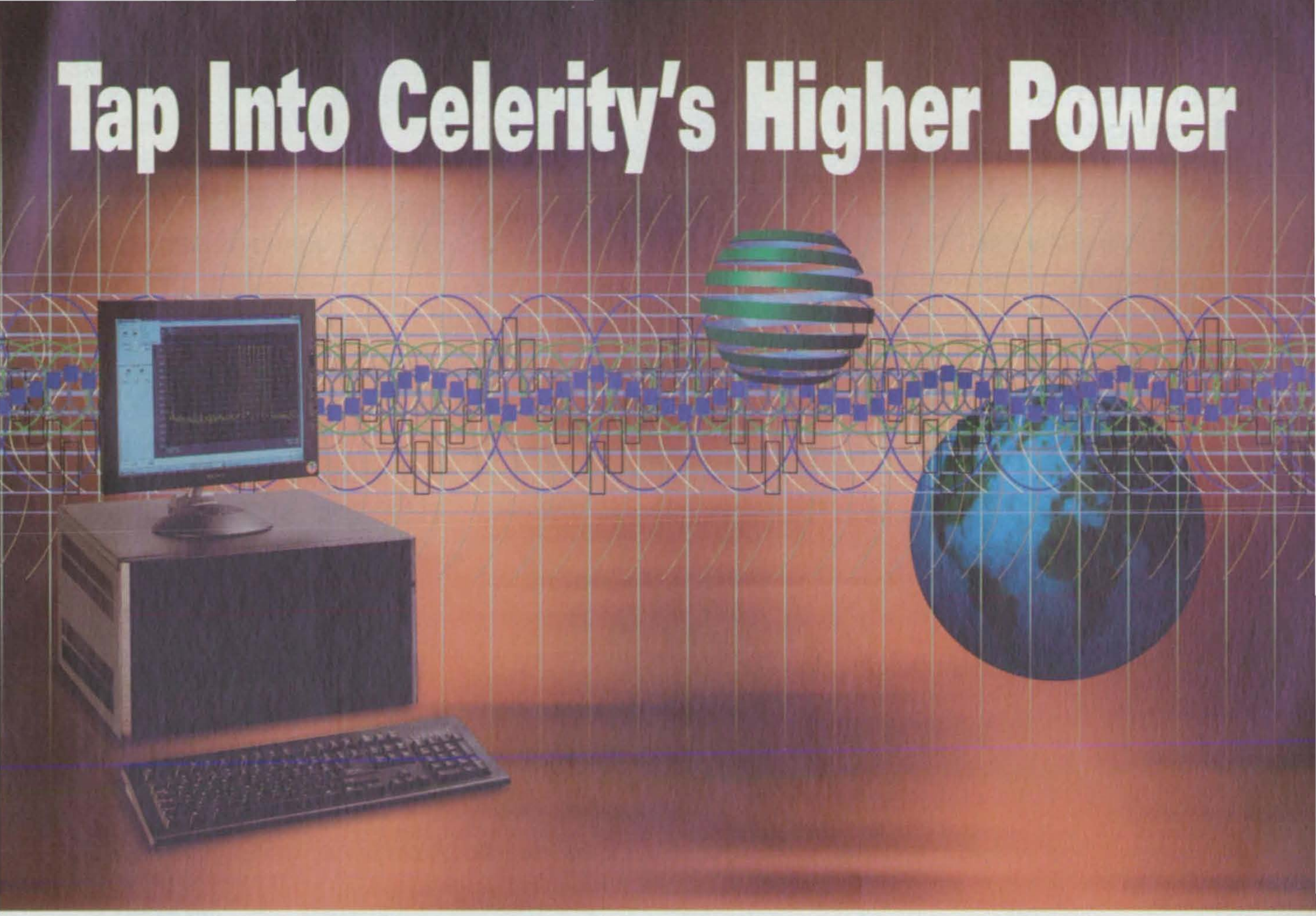

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NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (609) 667-7737 for the FLC coordinator in your area.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Carolina Blake
(650) 604-1754
cblake@mail.arc.nasa.gov

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Jenny Baer-Riedhart
(661) 276-3689
jenny.baer-riedhart@dfrc.nasa.gov

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merle.mckenzie@jpl.nasa.gov

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Kennedy Space Center
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Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Sam Morello
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s.a.morello@larc.nasa.gov

John H. Glenn Research Center at Lewis Field
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Larry Viterna
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cto@grc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Sally Little
(256) 544-4266
sally.little@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
(228) 688-1929
kirk.sharp@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

Joseph Allen
National Technology Transfer Center
(800) 678-6882

Ken Dozier
Far-West Technology Transfer Center
University of Southern California
(213) 743-2353

Dr. William Gasko
Center for Technology Commercialization
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(508) 870-0042

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Chris Coburn
Great Lakes Industrial Technology Transfer Center
Battelle Memorial Institute
(440) 734-0094

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

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gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Wayne P. Zeman
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Cleveland, OH
(216) 586-3888

B. Greg Hinkebein
Mississippi Enterprise for Technology
Stennis Space Center, MS
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Julie Holland
NASA Commercialization Center
Pomona, CA
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Marty Kaszubowski
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Hampton, VA
(757) 865-2140

NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.

Reader Forum

Reader Forum is dedicated to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a technical problem, or an answer to a previously published question, post your letter to Reader Forum on-line at **www.nasatech.com,** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864. Please include your name, company (if applicable), address, and e-mail address or phone number.

I need a piece of equipment electrochemically etched. Can someone give me a simple rundown of how this is performed? I am having difficulty locating information.

Tracy Chesnutt
tracy_chesnutt@hotmail.com

I'm trying to increase safety for a set of concrete stairs in an area that is problematic for normal lighting solutions. One brainstorm was painting the stair noses with glow-in-the-dark paint. I have only been able to find it in small quantities in the children's section of department and toy stores. The children's version washes away and abrades quickly. Does anyone know of an all-weather version that can be walked on?

Leilehua Yuen
yuen@ilhawaii.net

I remember seeing an article in the February/March 2000 timeframe in *NASA Tech Briefs* regarding an additive for the R134a-based automotive air conditioning system. Apparently, this was a by-product that was developed from a much larger program in support of NASA. Unfortunately, I cannot locate the vendor of this product. The name was "QuickStart" or "QuickBoost." Can you help?

Dave Glasscock
david.glasscock@faa.gov

*(**Editor's Note:** Dave, the additive is Qwik-Boost, marketed by Mainstream Engineering in Florida. The article appeared in the March issue of the Air Force Research Laboratory's* Technology Horizons *magazine, which you received with* NASA Tech Briefs. *For more information, call the Air Force's free service, Tech Connect, at 800-203-6451.)*

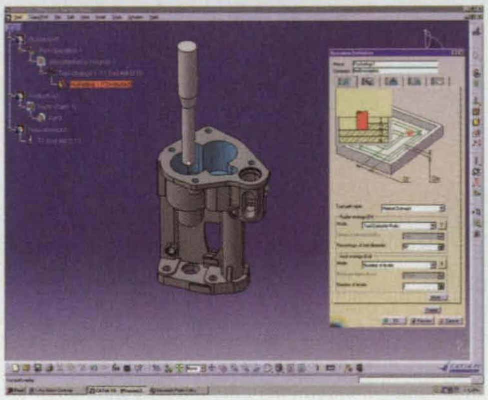
I read in your June Reader Forum about "Technologies Wanted," specifically the Transmission Technologies. We are involved in developing a gearing technology and are interested in contacting the relevant individuals looking for such a technology. Thank you.

Dr. Thomas D. Smith
New Century Engineering
tomsmith@ieee.com

*(**Editor's Note:** Tom, you can find details on the Wheeled Mobility Project's technology opportunities on the project web site: www.rti.org/technology/wheelchairs, or contact Stephen Bauer of the Rehabilitation Engineering Research Center on Technology Transfer at smbauer@cosmos.ot.buffalo.edu. Stephen and the rest of the RTI team appreciate the interest shown by* NASA Tech Briefs *readers in submitting technology solutions for the Wheeled Mobility Project.)*

UpFront

PRODUCT OF THE MONTH



IBM Engineering Solutions, Dallas, TX, has released CATIA Version 5 Release 4 CAD/CAM/CAE software for both 2D and 3D design that incorporates 12 new products and 39 enhancements. Available for Windows and UNIX, the new release features improvements in mechanical CAD, shape design and styling, manufacturing, analysis, cabling and DMU, and process coverage. It also incorporates standard parts catalogs, sheetmetal design integration, structure design, large assembly management, generative and interactive drafting, and a 2.5-axis machining product. A 3D viewer lets designers visualize a selected edge in a generated 2D view by its corresponding face in the 3D part. Users can generate a Bill of Materials in any view, and can edit call-out graphic properties and profiles.

For More Information Circle No. 756

Putting Your Best Face Forward

A digital human-image animation computer system called Digital Personnel is being developed at NASA's Jet Propulsion Laboratory in Pasadena, CA. It can use the smallest units of speech — phonemes — to manipulate a person's facial movements in an image. The system is driven by language rather than by manual animation controls. While development is only in early stages, the eventual result will be photorealistic animation of a person speaking. The system will make it possible to use an image of any human face and make it appear to be speaking naturally. With a videophone, it would be possible to have the option of always portraying the image you wish.

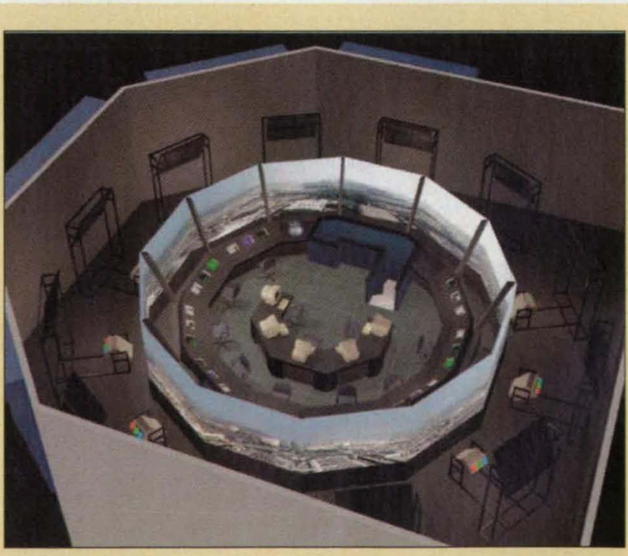
Communication capabilities are being designed for this technology to allow it to work efficiently over telephone as well as data lines. The system uses lower bandwidth, allowing broader use of the technology while also preserving the appearance of reality in the speaking facial image. Graphco Technologies (Newton, PA) has acquired the exclusive worldwide rights to Digital Personnel, the patent pending technology with potential applications in e-commerce, e-support, broadcasting, distance learning, video games, and motion pictures.

For more information, visit http://www.jpl.nasa.gov.

FutureFlight in Action

In the February UpFront, we told you about the opening of NASA's FutureFlight Central facility, a full-scale virtual airport-control tower at NASA's Ames Research Center in Moffett Field, CA, designed to test ways to solve potential air and ground traffic problems at commercial airports. Now, the San Francisco International Airport (SFO) Commission has selected FutureFlight Central to evaluate new tower positions, runway configurations, and aircraft movements before beginning new construction.

FutureFlight Central is the world's only walk-in, full-scale, 360-degree airport simulator; the facility can house as many as 12 air traffic controllers, and can represent the busiest US airport towers in size and capability. Using the facility, SFO airfield planners, Federal Aviation Administration (FAA) air traffic controllers, and others will help select the best location for a new tower. The simulator's artificial world changes in real time; scenes evolve, airplanes come and go, and weather changes. Consoles are at each controller's location showing radar, weather maps, runway lights, and touch-screen controls, in addition to other readouts. Once they put a new airport data set into their computers, researchers can switch to the new artificial airport in moments.



"We are able to represent any airfield in existence or as planned for the future," said Nancy Dorighi, FutureFlight Central facility manager. "We can measure the impact of a change on the airport's capacity, and let the controllers try it first-hand, all before anything is built."

For more information, visit http://ffc.arc.nasa.gov.

A New Century of Emerging Technologies

Technology 2000, the 11th annual conference for technology partnerships, licensing, and commercialization, will be held October 31 - November 2, 2000, at the Meydenbauer Convention Center in Seattle, WA. Sponsored by the Air Force Research Laboratory, NASA, *NASA Tech Briefs*, the Federal Laboratory Consortium Far West Region, other federal agencies, and industry partners, the event showcases new and emerging technologies from industry and government. Technology 2000 will be collocated with two companion events. The third annual Small Business Tech Expo will showcase the latest resources and technologies for launching new products and developing strategic partnerships. The National Small Business Innovation Research (SBIR) Conference will provide access to the nation's largest (over $1.2 billion per year) source of early-stage technology financing for small high-tech firms. Exhibitors will display the latest in electronics, mechanics, materials, manufacturing, software, and R&D innovations. Following are some of those innovations developed by the Air Force Research Laboratory (AFRL) and NASA. For more information on Technology 2000, visit the web site at www.T2Kexpo.com.

AFRL - Advancing Air Force Innovations

The Air Force Research Laboratory (AFRL), headquartered at Wright-Patterson Air Force Base, OH, is responsible for the Air Force's science and technology program, including basic research, exploratory development, and advanced development. Overall, the AFRL is responsible for planning basic research to ensure continued technological superiority; developing and transitioning new technologies for Air Force weapon systems and their supporting infrastructure; and ensuring responsive technical support in the event of urgent problems.

The laboratory is the Air Force's manager for technology transfer to, and exchange with, civilian enterprises. It also manages the Air Force's Small Business Innovation Research (SBIR), Dual Use, Science Fair, and Independent Research and Development programs. The lab's technology hotline, Tech Connect (1-800-203-6451), responds to internal and external requests for technology research and assistance.

The AFRL is organized along nine technology disciplines, located throughout the United States, plus an office for managing national and international basic research. Each discipline is assigned to a single directorate, with the responsibility to perform, procure, and synthesize basic research, exploratory technology development, and advanced technology development in that research area.

The following seven AFRL directorates will be represented at Technology 2000:

- **Directed Energy Directorate**, headquartered at Kirtland Air Force Base, NM, emphasizes the integration and transitioning of research technologies into military systems used by operational commands and maintained by Air Force Materiel Command. Areas of research and development include optical systems, high-power microwave technologies, lasers, and leading-edge space capabilities.
- **Human Effectiveness Directorate**, headquartered at Wright-Patterson, develops, integrates, and transitions science and technology products for training personnel, protecting and sustaining crew members, and improving human interfaces with weapon systems.
- **Information Directorate**, headquartered at Rome, NY, develops information technologies for aerospace command and control, and their transition to air, space, and ground systems.
- **Materials and Manufacturing Directorate**, headquartered at Wright-Patterson, develops new materials, processes, and manufacturing technologies for use in aerospace applications including aircraft, spacecraft, missiles, rockets, and ground-based systems and their structural, electronic, and optical components.
- **Propulsion Directorate**, headquartered at Wright-Patterson — with additional facilities at Edwards Air Force Base, CA — leads national programs to develop air and space vehicle propulsion and power technologies. Focus areas include turbine and rocket engines, advanced propulsion systems, fuels and propellants for all propulsion systems, and most forms of power technology.
- **Sensors Directorate**, headquartered at Wright-Patterson — with additional facilities at Hanscom Air Force Base, MA, and in Rome, NY — conceives and develops technologies that enable U.S. warfighters to find and precisely engage the enemy, while eliminating the enemy's ability to hide or threaten U.S. forces. This directorate collaborates with other AFRL directorates and DOD organizations to develop sensors for air and space reconnaissance, surveillance, precision engagement, and electronic warfare systems.

The AFRL's Starfire Optical Range conducts research and field experiments for the development of technologies for controlling high-energy, ground-based laser beams and high-resolution objects in space. (Copyright © 1998 Marble Street Studio)

- **Space Vehicles Directorate**, headquartered at Kirtland Air Force Base — with a major component at Hanscom Air Force Base — develops and transitions space technologies for more effective, affordable warfighter missions. This directorate also leverages commercial, civil, and other government resources that ensure America's defense advantage.

The AFRL directorates will showcase the following cutting-edge technologies at Technology 2000. For additional information, visit www.afrl.af.mil/techconn/index.htm.

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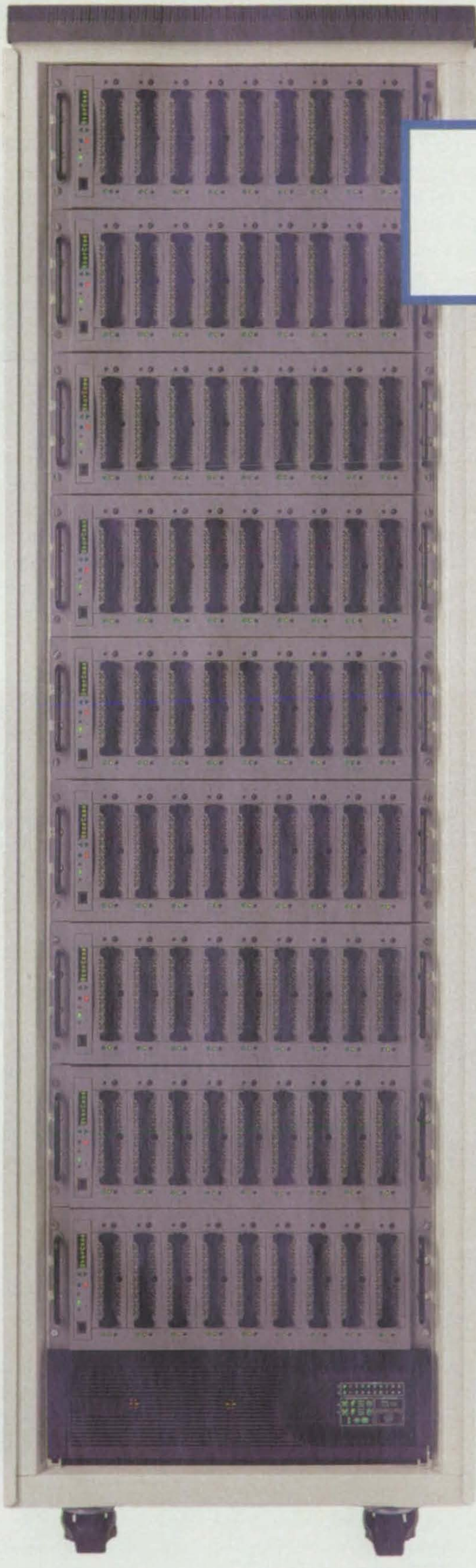

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- User Interface (UI) module for monitoring, reporting & set-up
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For More Information Circle No. 526

Advanced Material Enables High-Temperature Capacitors

Current state-of-the art (SOTA) power capacitors are becoming unreliable in military systems due to the high-temperature operating environment. Under the High Temperature Dielectric Program led by the Propulsion Directorate's Electrical Technology Branch (AFRL/PRPE), a Fluorene Poly Ester (FPE) capacitor film was developed with properties superior to the SOTA polycarbonate and polypropylene films. While current SOTA capacitors have a temperature capability of 125° C, FPE film can be used to produce capacitors that operate at up to 250° C. This film also has twice the voltage breakdown strength of polycarbonate films. These characteristics allow the production of capacitors capable of handling the temperatures seen in current weapons systems. Power capacitors fabricated with the FPE film feature a 40% weight reduction and a 30% increase in reliability.

Several commercial applications for high-temperature capacitors have been identified including "in hole" oil well applications, aircraft engine ignition systems, "under the hood" automotive systems, and medical defibrillators. A capacitor-grade 12-micron FPE film has been made available to capacitor manufacturers, and there also is a need for thinner (2- to 6-microns) films. Efforts by AFRL/PRPE have resulted in one firm working to produce the casting process for these thinner films; two other firms will use the casting process in a production mode.

Breakthrough in Fuel Filter Technology

Introduction of the +100 thermal stability additive into aviation turbine fuel has sparked a technology breakthrough in the filter/coalescer systems used to remove dirt and water from fuel. The +100 additive, developed by the Propulsion Directorate's Fuels Branch (AFRL/PRSF) to minimize maintenance costs associated with fuel degradation, disarms the currently fielded filter/coalescer systems. Consequently, the additive must be injected into the fuel downstream of the filter/coalescer units. AFRL/PRSF and the San Antonio Air Logistics Center (SA-ALC) have been working with filter companies and the commercial-fuels community to remedy this problem by updating filter/coalescer technology.

The Air Force has adopted a commercial specification (API 1581) for filter testing. The new specification has three categories: "C" for commercial-aviation fuel, "M" for military-aviation fuel including all mandatory additives, and "M100" for military fuel with all mandatory additives and the +100 additive. M100 is the toughest on the filter/coalescer system because it addresses the challenge presented by the +100 additive.

Facet International, a filter company based in Tulsa, OK, recently made an advance in filter/coalescer technology that meets the M100 challenge. In December 1999, Facet's coalescer and separator elements were tested against the new API 1581 M100 protocol and successfully passed all test criteria. The Facet filter element is a drop-in system that requires no modification to existing Air Force fuel-handling hardware. SA-ALC personnel are working to transition the new filter to the field. The new filter elements will aid in the transition of the +100 additive to all military and commercial aircraft and provide cleaner fuel for all aviation-fuel users.

Silicon Carbide MEMS

The AFRL's Propulsion Directorate's Power Division has developed advanced plasma etching techniques for silicon carbide (SiC) devices — including optimal gas ratio mixtures and operating pressure regimes for etching SiC using sulfur hexafluoride (SF6) diluted with argon (Ar) and helium (He). These techniques are essential for high-power switch and high-temperature Micro Electro Mechanical Systems (MEMS) or Micro Optical Mechanical Systems (MOMS) fabrication. The research achieved electronic-device and MEMS-pattern definitions that yield desired profiles, minimal physical damage, high etch rates, mask selectivity, large aspect ratio features, and minimal source gas and effluent hazard. The most significant accomplishments were the development of a tool and operating parameters that obtain high anisotropic etch rates with excellent surface smoothness.

Applications include pressure and temperature sensors, high-temperature integrated circuits, improved power devices, high-voltage switch, and power conditioning uses in utilities, automotive sensors, and medical implants. Tech-transfer options include the transfer of the tool design and operating parameters (including specs or instruction to help organizations build and use the process independently), and collaborative efforts and research to further scale up the process.

"Vision Spaceport" Initiative

NASA's Kennedy Space Center (KSC), FL, will sponsor an exhibit exploring options for 21st-century space travel. When routine, commercial spaceflight becomes a reality, state-of-the-art "spaceport" facilities will be required to accommodate a variety of reusable launch vehicles (RLVs) that will take off and land much like today's commercial airplanes. KSC is leading the Vision Spaceport initiative — the first joint-sponsored research agreement between KSC, industry, and academia. Partners include NASA's Ames Research Center, Boeing, Lockheed Martin, SAIC, Quantum Technology Services, and the University of Central Florida.

The "spaceport as airport" is expected to become a reality in the 21st century. Spaceport developers from Florida, California, and Nevada already have begun investing to establish hubs for commercial space travel.

Primary goals and challenges include reducing the cost of space transportation and payload delivery while improving flight rates and safety. A model is being developed to provide system-design information in various categories, including identifying required spaceport facilities, estimating facility and support equipment acquisition cost and work-force size, operations-cost summary, and calculating vehicle and spacecraft processing time and system flight rate.

The Vision Spaceport partnership seeks collaboration and expertise in space-operations performance benchmarking, technology roadmapping, cost modeling, facility visualization, and related fields. Visit KSC's Vision Spaceport exhibit at Technology 2000, or visit www.visionspaceport.org.

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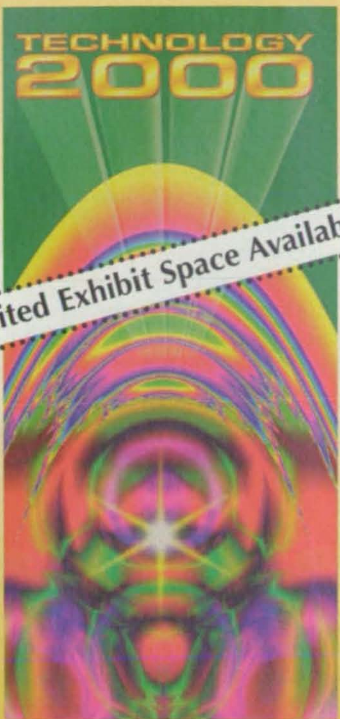

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Helen Stinson, SBIR Program Manager, Marshall Space Flight Center

Helen Stinson is the Small Business Innovation Research (SBIR) Program Manager at NASA's Marshall Space Flight Center (MSFC) in Huntsville, AL. Her 17-year tenure at NASA has included engineering roles in the Structural Analysis and Dynamics Laboratory, where she assisted in the development and analysis of the Space Shuttle main engine's alternate turbopump and Spacelab payloads.

NASA Tech Briefs: **How do the SBIR/STTR programs at each field center (such as MSFC) fit into the overall structure of NASA's SBIR/STTR program?**

Helen Stinson: All ten NASA field centers are involved in SBIR in the topic/subtopic development process, proposal evaluation and selections, contract award, contract monitoring, and follow-up. STTR is similar, except that NASA's Jet Propulsion Laboratory (JPL) does not participate because that organization can team with a small business in proposal submission.

NTB: What role does the SBIR office at MSFC play in the Phase I selection process?

Stinson: We are responsible for the evaluation and selection of all proposals assigned to our center. This office interfaces with other centers, NASA Headquarters, Strategic Enterprise representatives, topic/subtopic managers, evaluators, the MSFC Procurement Department, MSFC's Office of the Chief Financial Officer, and small businesses. The final selections are made by the SBIR/STTR Chief Executive, Carl Ray, at NASA Headquarters.

NTB: How do these programs benefit the U.S. technology base?

Stinson: We are able to fund high-risk, high-payoff projects that mainline programs can't afford due to schedule/resource constraints. Mainline programs can fund a project as a Phase III, once we've proven the technology.

NTB: What topics and subtopics are most likely to be proposed by MSFC researchers for the next solicitation?

Stinson: Our lead topics/subtopics will be aligned with our three mission areas: Space Transportation Systems Development, Microgravity, and Space Optics Manufacturing Technology.

NTB: What are some of the most successful Phase III projects to emerge from Marshall's SBIR program?

Stinson: Quantum Devices (Barneveld, WI) developed LED-based lighting technologies for wound healing and for cancer treatment, using light-emitting diodes (LEDs) originally developed for NASA Space Shuttle plant-growth experiments. Research has focused on photodynamic therapy (PDT), an adjunctive cancer therapy in which light-sensitive, tumor-treating drugs are injected intravenously. LED light activation allows the drugs to destroy cancer cells, leaving surrounding tissue virtually untouched. Another example is the TeleOPerations System (TOPS™) developed by AZ Technology (Huntsville, AL). This set of Internet tele-operations and collaboration tools uses commercial PCs and web-based communications to remotely control and monitor systems. TOPS provides commanding and telemetry distribution/display via Internet Protocol-based communications and web browsers. Many other success stories are available online at www.nasasolutions.com/SBIR/sbirsuccess.html.

NTB: What advice do you have for small businesses preparing their first proposals?

Stinson: I would suggest that they utilize resources from state or local Small Business Offices, review current information available at the SBIR web site at http://sbir.nasa.gov, review other NASA web sites, attend SBIR conferences/workshops, and talk to NASA technical/program personnel during the allowable period.

A full transcript of this interview is available online at www.nasatech.com. Ms. Stinson can be reached at helen.stinson@msfc.nasa.gov.


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LabVIEW 6i: An Impressive Tool for Data Acquisition

Steven S. Ross

The latest version of National Instruments' LabVIEW graphical programming language for building on-screen "virtual instruments" is faster, more feature-laden, and prettier to look at. It is also Web-friendly. Quality control and process control specialists will benefit the most. I had a chance to look at the final pre-production code in July, just before press time.

At its most basic, LabVIEW is a graphical programming language. You use its symbolics to map out a process and build an on-screen "virtual instrument" (VI) to monitor and control external data acquisition or processes. NI says most of its sales are to production environments, where LabVIEW can configure, say, testing of cell phone circuits at the end of the line. LabVIEW can also monitor lab-level experiments, or mile-long chemical plants.

I last ran across LabVIEW in a professional setting, where it was used to control production in a bench-sized chemical plant making coatings for strain sensors. The software first shipped in the mid-80s. NI, among others, supplies plenty of instrumentation that can hook to standard computers and feed a LabVIEW-built virtual instrument. For the review, NI sent

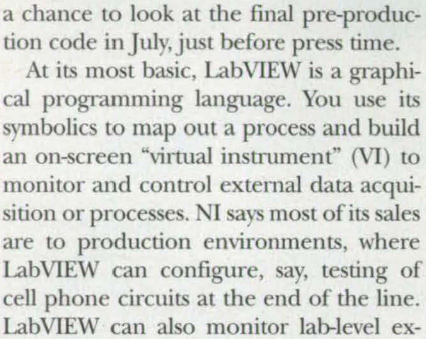

Figure 1: Control panel of virtual instrument (in this case, two external data acquisition modules). These panels can be built up easily by dragging display and control items from palettes (on the left in this view).

along one of its DAQCard-1200 PCMCIA cards and a function generator to make my Windows 98 laptop think it was connected to a bunch of external sensors.

There is no practical limit, aside from power of the computer it runs on, to the complexity of processes or the amount of data LabVIEW 6i can control. But there is a limit to how complex a system anyone might want to build using pre-designed blocks. This latest version pushes the limit quite far. After quickly determining that the interface is quite responsive on my test machine — with a modest 450-MHz Pentium III and 64 MB of RAM — I spent more time checking points at which users could be led astray.

How easy is it, for instance, to build an instrument that records all incoming data but flags transmission lapses and discards startup resonance and repetitive zeros, and spans for calibration? Can all or almost all of the data processing be done within LabVIEW, or do you have to risk exporting the data to another package to run the stats or draw a nice chart? How good is the array of signals LabVIEW can send out to tickle a circuit being tested? How easily does LabVIEW share data with the rest of the enterprise?

In a word, LabVIEW 6i was impressive — on all counts. There may be better packages for running predictive mechanical simulations and for handling "fuzzy" data (economic data, for instance). But in its broad niche, LabVIEW 6i is a robust, mature package that won't steer you wrong. This latest version, for instance, has a new "digital I/O" virtual instrument display to represent timing data and digital patterns. That's an easy way to handle zeros and spans — you define the time segments to ignore. The tutorials, wizards, and help files are detailed and easy to navigate, and include AVI animations with sound.

As you might expect these days, you can also stream LabVIEW-generated data across the Web, and read it on LabVIEW-built virtual instruments. The VIs display on your browser once you download the free plug-in from www.ni.com/labview. You do not need LabVIEW running on the same machine as the browser, either. I didn't test the idea, but it seems almost trivial to split up a large stream of, say, ten measurements and send two or three to each of a half-dozen specialists around the world in real time as data are gathered. There's an ActiveX development system for this, so use Internet Explorer, not Netscape.

Once you design your software in LabVIEW 6i, you compile it — LabVIEW is a true 32-bit compiler. You can create executables and shared libraries (DLLs in Windows-speak). Compiled programs run faster. VIs developed on older versions run fine in 6i. Visual Basic is a nice match for LabVIEW developers. The links to Java are still being developed. The latest version offers fast Fourier transform routines that are fast indeed — NI says they are 20 to 30 times faster than in earlier versions — and that can also be nicely deconstructed.

LabVIEW 6i comes in three versions — the base package, full development system, and professional development sys-

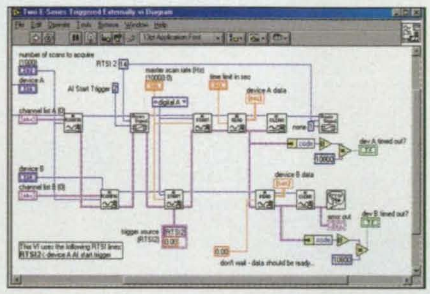

Figure 2: Block diagram for VI in Figure 1. You build the diagram after you build the control panel, using a functions palette to define items. Note the icon in upper right corner; it identifies this VI. VIs can be used within other VIs.

tem. There are add-ons for datalogging and alarm triggering, machine vision and image processing, SQL, Internet functions, process control, PID and fuzzy logic, system simulation and design (linear and nonlinear systems), sound and vibration, signal processing (including wavelet), and optical character recognition. Prices start at $995. Expect to spend $2,000 or so for everything you need. Upgrades from older versions are $395.

LabVIEW runs on many platforms, including any computer that supports Windows 9x or NT, Power Mac OS 7.6.1 or later, UNIX, and major Linux distributions.

For details and ordering information, visit www.ni.com/labview/.

Steve Ross is an associate professor of professional practice at Columbia University's Graduate School of Journalism, where he runs the science writing program and teaches analytical journalism.

PHOTONICS Tech Briefs

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Modeling Optical Thin-Film Stacks

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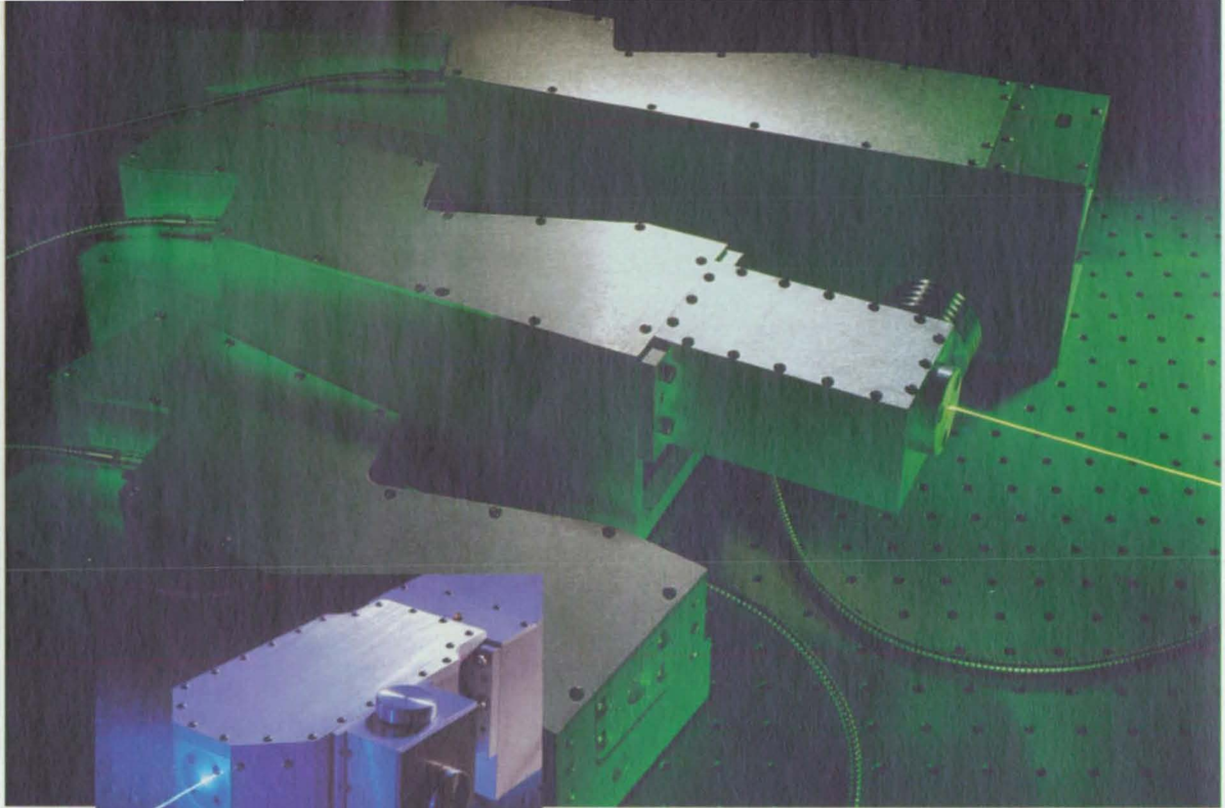

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Supplement to *NASA Tech Briefs'* September 2000 Issue Published by Associated Business Publications

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***On the cover:** Rodenstock Precision Optics offers a large assortment of filters and other accessories to optimize imaging performance with high-quality lenses.*

Photo courtesy Rodenstock Precision Optics.

Modeling Optical Thin-Film Stacks

TracePro®'s optomechanical program allows thin-film stacks to be analyzed as a component of an optical surface property.

Optical analysis software has evolved over the past several years to provide comprehensive capabilities, through the combination of advanced solid modeling and extensive generalized geometrical ray tracing. As the demands on optical analysis software increase, more phenomena must be modeled during the simulation. Simple models of reflection and transmission have been displaced by tabular interpolation and now include more precise models, namely thin-film stacks. Stack modeling not only provides reflection and transmission but also the effects of polarization, wavelength dispersion, and incident angle, all without an enormous table of data.

Optomechanical analysis tools have been built on solid modeling engines, such as ACIS®, made by Spatial Technology, Inc., and provide an interface to construct new geometry and apply optical properties enabling ray-trace simulation. These programs support data interchange formats, permitting the use of solid-model data from other CAD software. TracePro® is one optomechanical analysis program that allows thin-film stacks to be added as a component of an optical surface property. Using stacks has the distinct advantage of added accuracy during the ray-trace simulation, provided the stack definition is obtainable from the coating manufacturer.

Reflection at an optical interface

We often think of the interaction at the interface between two optical media to be defined by the refractive-index difference, giving rise to a Fresnel reflection and transmission. For example, when visible light hits a piece of glass, about 4 percent of the light is reflected and the rest transmitted. This common phenomenon is easily observed by looking out a typical window and seeing one's dim reflection in the glass. In precise optical imaging systems, this partial reflection is a common cause of stray light, specifically a ghost reflection. During the modeling of this reflection and transmission, one must include the effects of incident angle, polarization state, and wavelength of the light—and even the temperatures of the media.

Many optical systems depend on optical coatings to perform useful tasks, such as separating or filtering light by its wavelength or polarization state, and reducing or enhancing the reflectivity of a surface. Color bandpass filters are used in projection systems to separate white light into red, green, and blue (RGB) components. Liquid crystal display (LCD) systems use coated beamsplitters to produce polarized light. Many systems employ antireflection coatings to reduce ghost reflections. These coatings are manufactured by depositing alternating thin layers of materials upon a substrate.

Figure 1 shows the effect of applying a single layer of magnesium fluoride (MgF_2) to Schott BK7 glass. The layer thickness is 0.125 µm or one quarter-wave optical thickness (QWOT) at 0.5 µm. The refractive index of both the coating material and glass vary versus wavelength, and the reflectance will vary accordingly as shown.

In TracePro, stacks are constructed of individual layers, each with a refractive index and thickness, and assigned to a surface in the solid model. The refractive index entries use a database of

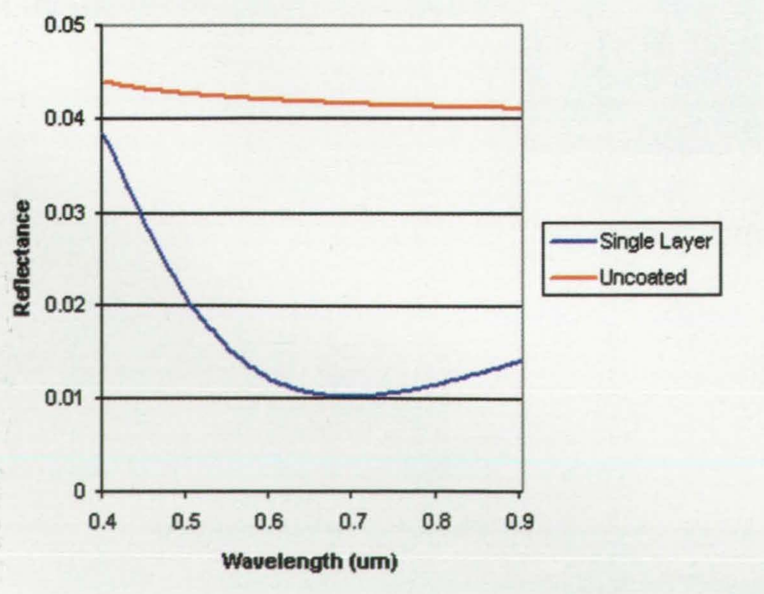

Figure 1. The effect of a single layer of magnesium fluoride on the reflectance of Schott BK7 glass.

material properties to define the index and absorption coefficients for the particular ray-trace wavelength and temperature. Stacks may be one or more layers, and are evaluated during a ray-trace simulation for a given incident angle, incident and substrate media. The substrate medium is determined by the material property associated with the object that contains the surface.

Stack evaluation is performed by a characteristic matrix algorithm, which is typical to optical thin-film design programs. Each layer is described by a 2-×-2 matrix that determines the components of the electric (or magnetic) field along the direction of propagation. By using a complex refractive index, metals and absorbing materials are modeled accurately. Two matrix initializations are used for the S-polarized light (TE wave) and the P-polarized light (TM wave). After multiplying the matrices from each layer together and applying an input-column matrix, the result provides the reflectance, transmittance, and phase change for both polarizations and is subsequently used to calculate the surface reflectance, transmittance, and polarization changes during the ray-trace simulation. A more complete description of this interaction may be found in "Principles of Optics" by Born and Wolf.

A polarizing beamsplitter

As an example, we can consider a MacNeille polarizing beamsplitter, which separates unpolarized light into two orthogonal linear polarized components. The beamsplitter is made from two similar glass prisms that have a dielectric coating applied at the interface between the two. Table 1 shows a typical seven-layer stack that is 98 percent reflective for S-polarized light and greater than 90 degrees transmissive for P-polarized light over the visible wavelength band. The design is optimized for 45-degree incident light. The prism input face is usually normal to the incident light, as shown in Figure 2. Provided that the light is well collimated, the output from the beamsplitter will be two linearly polarized beams.

Figure 3 compares the transmission performance of the MacNeille coating for both polarizations and two incident angles. At the design angle of 45 degrees, the difference between the two polarizations is very distinct and thus gives the desired polarization-separating performance. At an incident angle of 30 degrees, we can see that almost all of the difference between the two polarizations is lost.

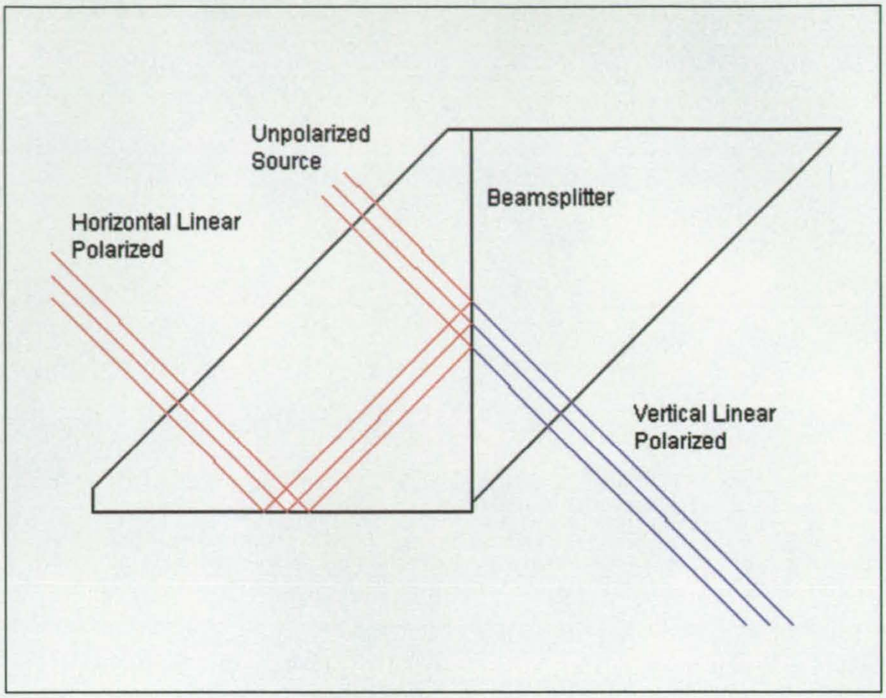

Figure 2. Polarizing effect of a MacNeille beamsplitter.

Incident Medium	Schott SF7
0.063 µm	Zinc sulfide
0.177	Magnesium fluoride
0.063	Zinc sulfide
0.177	Magnesium sulfide
0.063	Zinc sulfide
0.177	Magnesium fluoride
0.063	Zinc sulfide
Substrate Medium	Schott SF7

Table 1.

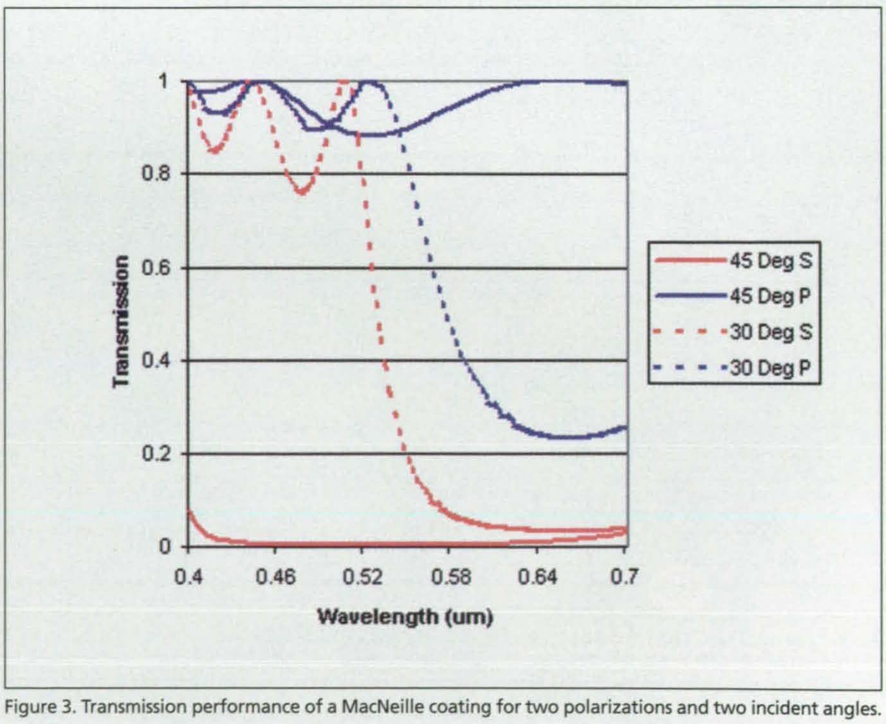

Figure 3. Transmission performance of a MacNeille coating for two polarizations and two incident angles.

We can investigate the effect of noncollimated light for this model by adding some angular dispersion to the incident beam. Figure 4 shows the results of an unpolarized beam entering the beamsplitter within a 30-degree cone. The higher incident angles of some of the rays will reflect from a prism surface due to total internal reflection, which is independent of the coating. The rays that do reflect and transmit from the coating at the prism interface lose much of the desired polarization state because both polarizations comprise each beam. Simply by looking at performance curves of the stack at various wavelengths and angles, we can deduce that this will occur. The benefit of including the stack calculation is that it allows the design evaluation of actual systems that do not have "perfect" input or predetermined ray paths when the effects of stray light and other aberrations are to be included in the analysis.

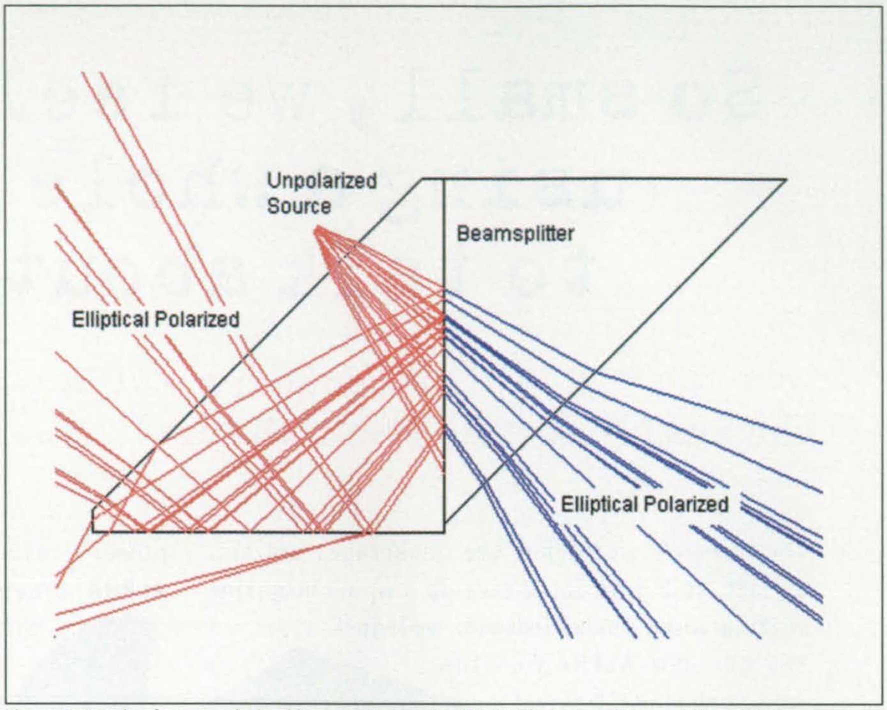

Figure 4. Result of an unpolarized beam entering the MacNeille beamsplitter within a 30-degree cone.

Improving performance analysis

Optical coatings, like all optical properties, are sensitive to incident angle. Unlike some properties, for example the refractive index of many optical glasses, the performance of coatings is not well suited to polynomial fitting, and generally needs an excessive number of data points to provide a suitable data set for tabular interpolation. The algorithms for stack evaluation are well known and relatively fast to compute for common coatings. As the stacks become more complex, with more layers and materials, however, the calculation time increases for each stack. But the effects of wavelength and angle become more complicated and can balance the increased simulation time by providing a better answer.

Unfortunately, the lack of availability of data is a significant drawback to using thin-film analysis to model optical coatings. Most notably, many designers and producers of optical coatings will not make the stack prescription available to outsiders. The accuracy of the calculation also depends on the material data for the refractive index and absorption over the wavelength range of the analysis. Finally, as with any manufactured component, stacks have thickness design tolerances that must be considered during the analysis and tolerance phases of the system design.

When optical systems are designed, the performance analysis only improves when additional data is added to make the model more accurate. TracePro, initially developed under a NASA SBIR grant to improve interoperability between optical and mechanical modeling programs, has evolved into a comprehensive virtual prototyping environment for a diverse range of optical systems. Optical thin-film stack analysis is one of many advanced simulation functions that make TracePro a unique program suited to today's optomechanical analysis needs.

For more information please contact the author of this article, G. Groot Gregory, vice president of Lambda Research Corp., 80 Taylor St., Littleton, MA 01460-4400; (978) 486-0766; e-mail: groot@lambdares.com; www.lambdares.com.

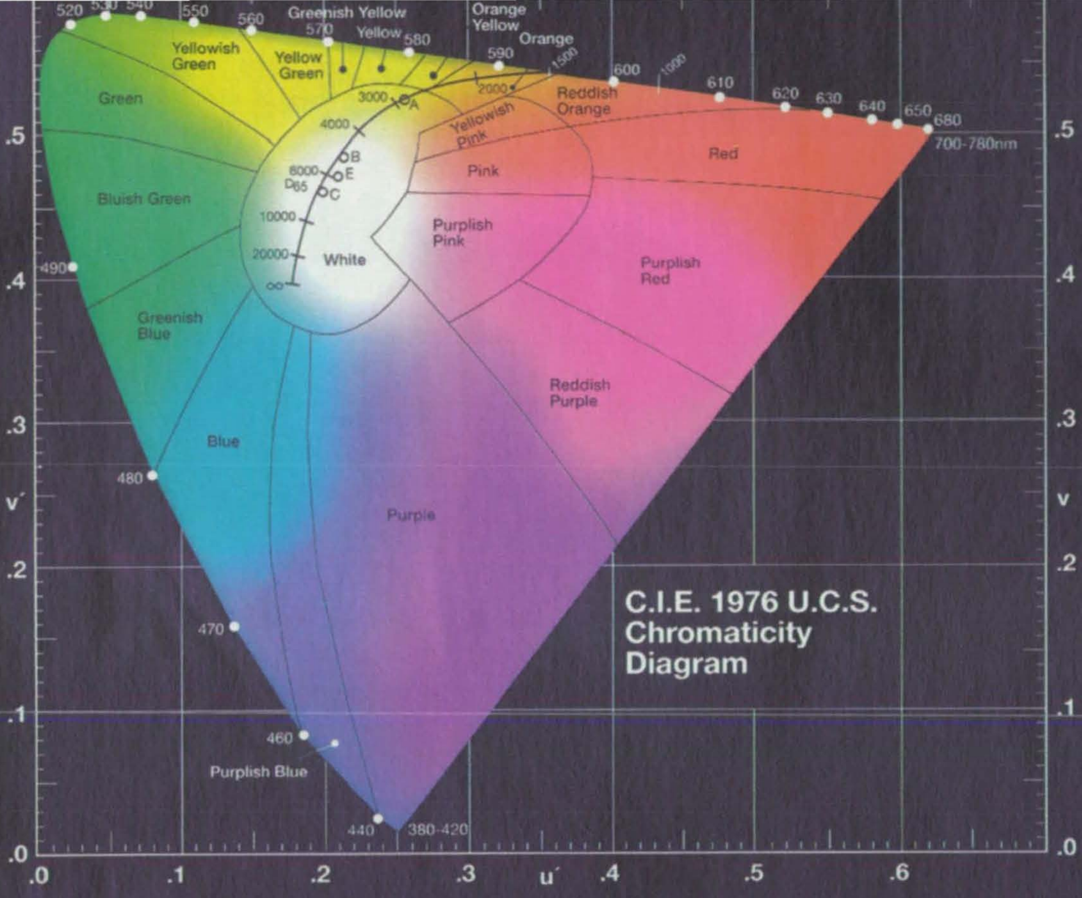

Diagram courtesy of Photo Research, Inc., "The Light Measurement People."

Time-Resolving Wind-Tunnel Pressure Data

Roper Scientific's CCD cameras and image intensifiers combine to speed up air-pressure measurements.

A new pressure-sensitive paint (PSP) technique has been tested at the NASA Ames Research Center's 11-foot Transonic Wind Tunnel. Called the time-resolved technique (PSPt), it employs the same high-performance CCD cameras and University of Washington paint currently utilized by NASA, but adds high-speed modulation capabilities to the camera and excitation lights. In the older technique, the brightness of the paint under steady illumination correlates to air pressure on the aircraft model's surface. In the PSPt technique, the time-resolved decaying brightness when illumination is switched off correlates to such pressure.

The anticipated improvements offered by the new technique consist of (1) elimination of the wind-off reference runs needed by the present "intensity" technique to calibrate the brightness of the paint, and (2) elimination of the image registration postprocessing required by the intensity technique.

This time-resolved approach has been developed for large-scale wind-tunnel testing by Innovative Scientific Solutions, Inc. (ISSI) of Dayton, OH, and Lockheed Martin Aeronautics Company (LMAC). For these tests, the surface partial pressure of oxygen on the model is measured and then easily converted to surface air pressure. While the standard intensity technique records the paint's brightness of luminescence under strong and steady illumination, the time-resolved technique measures the time-constant of the paint's decaying brightness after the illumination lights are switched off suddenly (Figure 1). Both the paint's brightness and time-constant are strong variables of the model's surface pressure. Recently, side-by-side evaluations of the two techniques have been conducted by Dr. J. H. Bell in the Ames Transonic Wind Tunnel.

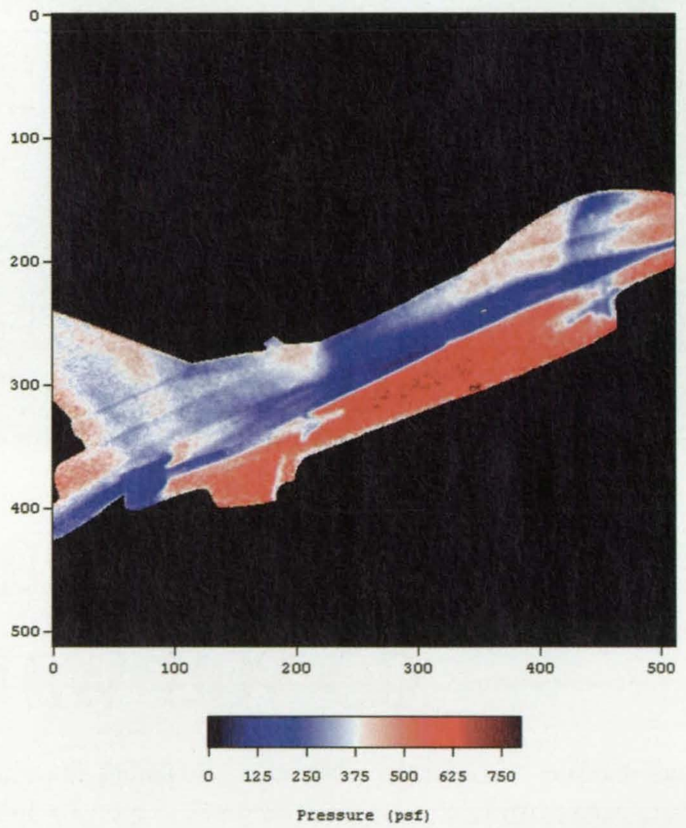

Figure 1. Image data acquired with the PSPt demonstration system.

Ideal for Transonic Tests

PSPt carries the requirement for additional equipment. It may not be as suitable for low-speed PSP testing, but seems ideal for transonic loads testing. The University of Washington FIB paint used with the intensified technique is also excellent for the time-resolved technique. The scientific-grade back-illuminated CCD cameras currently in use at Ames and the Arnold Engineering Development Center (AEDC) are easily adapted for the fast (microsecond) shuttering required to determine the paint's time-constant variations (Figure 2). New illumination lights capable of sharp cutoff are also required.

To achieve the fast shuttering, a Roper

Scientific image intensifier (Figure 3) and relay optic have been fitted to one of LMAC's Roper CCD cameras. The intensifier is operated at very low gain to avoid adding too much noise to the images. The modified configuration allows the camera to take precisely controlled exposures during the paint's luminescence decay.

The intensifier comprises a photocathode, a microchannel plate, and a phosphor screen. A fraction (called the quantum efficiency, or QE) of the photons incident on the photocathode is converted into electrons. Single photoelectrons are converted into clouds of electrons by the microchannel plate (MCP), which acts as a distributed electron multiplier. The electrons released from the MCP then strike the fluorescent screen (phosphor) and cause it to emit far more light than was incident on the photocathode. In the traditional configuration, the voltage between the photocathode and the input of the MCP is used to switch the intensifier on and off. If the photocathode is electrically biased more positively than the MCP, electrons will not enter the MCP and the intensifier is gated off. If the photocathode is negatively biased, electrons will be accelerated toward the MCP and the intensifier is turned on.

The PSPt demonstration system utilizes an 18-mm Gen II image-intensifier tube that features a "balanced response" photocathode designed to deliver similar QE at both red and blue wavelengths. High-performance Gen IV image-intensifier tubes are also available. The Gen IV tube combines a gallium arsenide (GaAs) photocathode with a high-resolution MCP. The low bandgap of the GaAs photocathode exhibits superior QE from the blue to the near-infrared spectral regions, while the 6-micron diameter of the plate's microchannels enables an overall resolution of more than 64 lp/mm.

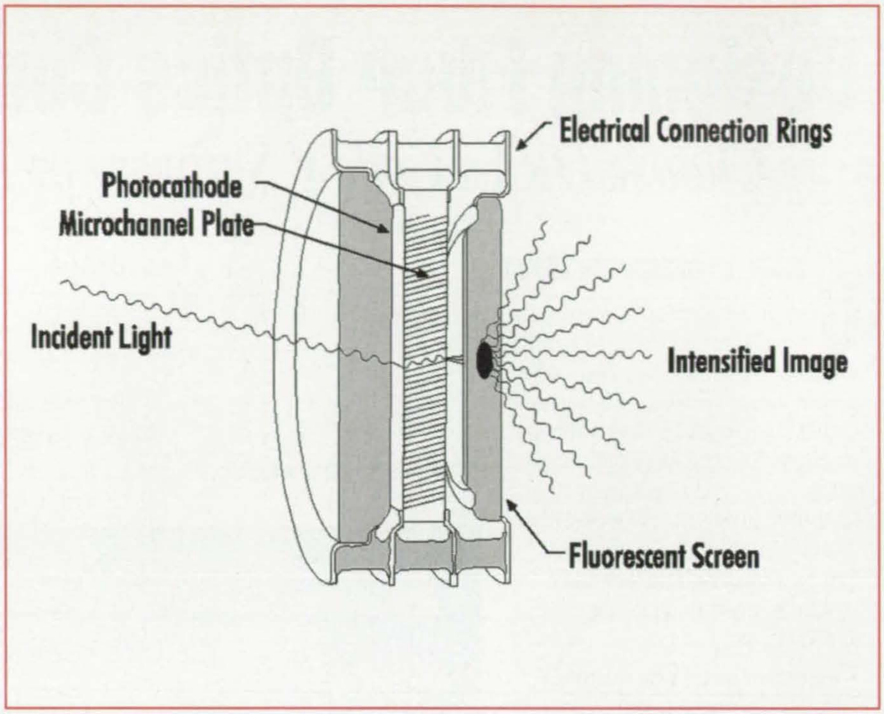

Figure 3. The construction of an image intensifier.

A lens-coupled relay optic was chosen for the PSPt demonstration system so that existing cameras can be retained. Use of a more sophisticated fiber-optic-coupled intensifier would require the purchase of new CCD cameras and vacuum hardening for operation in the plenum of transonic tunnels. Roper Scientific is designing improved lens-coupled optics for its 1024-×-1024-pixel CCD cameras, which are already in use at many tunnels.


Figure 2. The PSPt demonstration system used at the Ames Research Center.

Encouraging Results

The requirement for extinguishing the excitation lights within a few microseconds has driven the development of super-bright blue LED lights by ISSI and AFRL/FIMO. LMAC, ISSI, Glenn Research Center, and AEDC provided such lights for the Ames test. Preliminary testing of the new technique was conducted at AEDC in September of last year, and personnel from AEDC assisted in the test at NASA Ames.

Results from the Ames test thus far are very encouraging. The intensity technique provided high-resolution pressure maps of the transonic flow and the equipment was installed in a nearly production-ready configuration. The intensity-derived pressures will be compared with pressures from the model's pressure taps and will be surface-integrated for comparison with the force and moment data. Pressures derived from the time-resolved technique will be compared with those from the more mature techniques.

This article was written by Larry N. Lydick of Lockheed Martin Aeronautics Company and Jeff Grant of Roper Scientific Inc. For more information, please contact Grant at Roper Scientific, 3440 E. Britannia Dr., Tucson, AZ 85706; (520) 547-2754; fax: (520) 573-1944; e-mail: jgrant@tucson.ropersci.com.

Improved Optical Fallout Monitor

This system can now be calibrated for real-time measurement of fallout in the field.

John F. Kennedy Space Center, Florida

Modifications have been made to upgrade the system described in "Optoelectronic Particle-Fallout Sensor" (KSC-11687), *NASA Tech Briefs*, Vol. 19, No. 4 (April 1995), page 17a. A description of the unmodified version of the system is necessary to place a description of the modifications in context:

This is a portable system that measures fallout of small airborne particles. The system includes a sensor module and a data-acquisition module, both of which are battery-powered and contain microcontrollers and other circuitry. The sensor module can operate either independently or under control by the data-acquisition module.

The sensor module includes a black acetal plastic housing with a top opening through which dust can fall onto a mirror. A portion of the mirror is illuminated by an infrared light-emitting diode (LED). When particles are not present on the mirror (and provided that the mirror is not scratched), the infrared light is reflected specularly by the mirror and absorbed by the black sides and top of the housing. When particles are present, the infrared light that they scatter is measured by a photodetector assembly. The optics are designed to minimize the detection of both ambient light and light scattered from surfaces other than that of the mirror. The photodetector output is amplified, digitized, and time-tagged as an indication of the particulate contamination of the mirror surface as a function of time.

To conserve battery energy, the sensor module is designed to operate for only a few seconds — just long enough to take a reading when it is commanded to do so. When separated from the data-acquisition module, the sensor module is turned on to take a reading by pressing a momentary-contact button switch. To increase sensitivity and facilitate discrimination against background signals, the infrared LED is turned off and on several thousand times during each sampling interval. The difference between the signals measured in the "on" and "off" states is averaged over the sampling interval to produce an output signal that contains relatively low noise.

To operate the two modules together, it is necessary to connect them via a ribbon cable. In this configuration, the data-acquisition module takes control of, and supplies power to, the sensor module. At time intervals selected by the operator, the data-acquisition module commands the sensor module to take readings and records both each reading and the time when it was taken. The module can later be connected to a computer to transfer the reading and time data to the computer for display and/or analysis and to program the data-acquisition module for subsequent readings. This completes the description of the unmodified version of the system.

The modifications were made primarily to overcome the following deficiencies of the unmodified version of the system:

- Sensitivity was not adequate for use in very clean environments;
- It was not possible to calibrate the system accurately by following commonly accepted practices;
- The system was not sufficiently thermally stable for use in non-temperature-controlled environments;
- The electrostatic and power-consumption characteristics did not satisfy requirements for use of the system in certain specific spacecraft-payload-processing clean rooms at Kennedy Space Center;
- It is now a one-piece instrument; and
- The instrument has RS-232 output and can be programmed remotely and used as part of a facility contamination monitor system.

The sensitivity of the system was increased by replacing a 12-bit analog-to-digital converter (ADC) with a new 20-bit ADC. The integrated-circuit chip of which the 20-bit ADC is a part affords additional digital filtering capabilities, which are exploited to increase the robustness of operation under adverse lighting situations. To accommodate the aforementioned circuitry, a circuit board was completely redesigned, with special attention paid to quality of signal and reliability. The redesigned circuit board supports additional features, including programming of operating parameters via a keypad, a current-loop or voltage analog output, and new power-utilization features. The overall number of integrated-circuit chips has been reduced, and the number of circuit boards has been reduced from 2 to 1.

The system now operates on modified software that provides, among other things, the ability to reprogram "on the fly" (without disrupting operation) to adjust such parameters as sensitivity ranges and data-taking intervals. (Previously, it was necessary to turn the system off, then back on again to put it in a programming mode.) The modified software makes it possible to reprogram or to download data from the system remotely by serial data communication via a cable.

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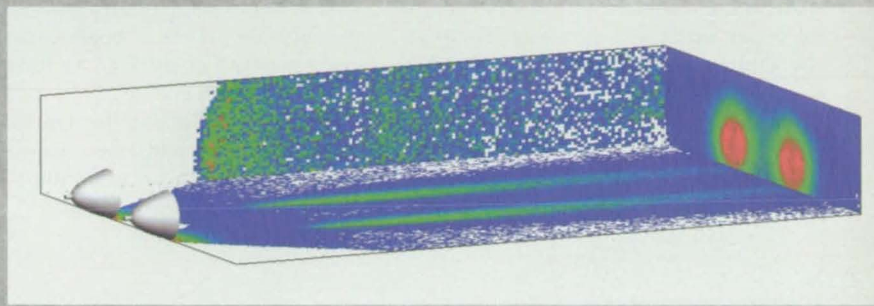
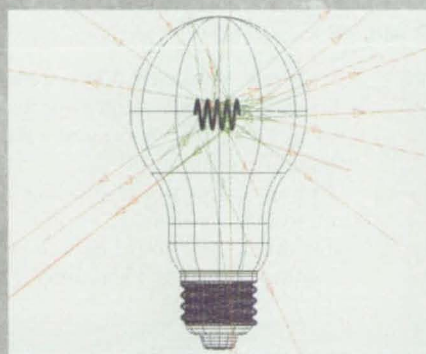
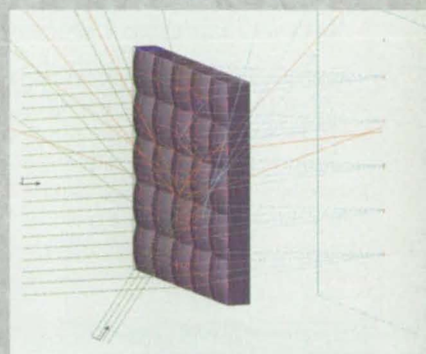
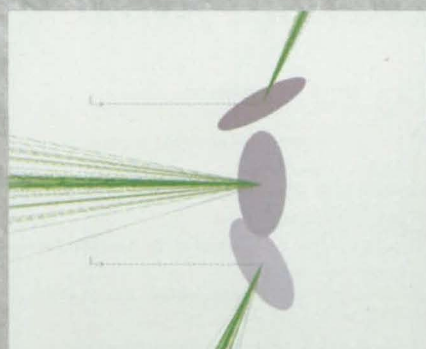


False color irradiance distributions are viewed anywhere "in place" on detectors of arbitrary shape.





Complex objects may be imported, like this IGES light bulb. Other objects, such as this lenslet array, are generated within OptiCAD.



BSDF/BRDF measured scattering data may be placed on any surface for accurate modeling of scattered light.

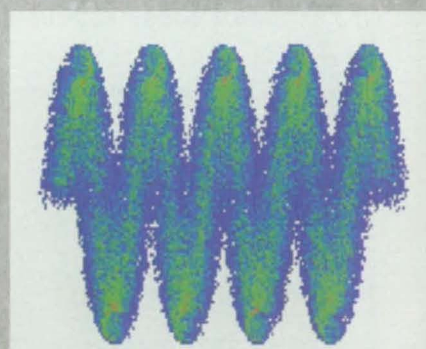


Image of a helical light source ray traced in OptiCAD. Light sources include parametric models, user defined, or tabulated ray data.

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A reference photodetector with an independent ADC was added. These components will make it possible to measure and hence correct for fluctuations in the output of the LED, thereby increasing the temperature stability of the system by an order of magnitude.

The mirror in the unmodified version of the system was replaced with a witness plate in the form of a silicon wafer bonded to an aluminum substrate. Holes in the aluminum substrate make it possible to scan the silicon wafer, by use of a semiconductor-wafer scanner, for extremely accurate analysis of the particulate contamination on the wafer; this makes it possible to perform acceptable calibration.

The optics have been simplified to reduce the number of surfaces through which light must pass, thereby increasing throughput of the light to the photodetectors. There is also now an option to use an LED with a wavelength of 935 nm in applications in which the shorter wavelength (880 nm) of the unmodified system would be problematic.

The electronic circuitry was modified to enable the system to operate on intrinsically safe power through an intrinsically safe barrier to enable use in hazardous environments. Finally, the electrostatic-charge issue was addressed by repackaging the system in an aluminum enclosure, which can be grounded.

This work was done by Paul A. Mogan of **Kennedy Space Center** *and Christian J. Schwindt, Timothy R. Hodge, and Steven J. Klinko of Dynacs Engineering Co. Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

This invention has been patented by NASA (U.S. Patent No. 5,412,221). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-6373. Refer to KSC-12105.

An Electro-Optical Frequency Shifter

Frequency of a laser beam would be shifted up or down by as much as several gigahertz.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed electro-optical apparatus would shift the frequency of a laser beam by a controllable amount within the range of about ±10 GHz. It would be a wide-band alternative to an acousto-optical tunable filter, which is limited to a frequency shift of about 100 kHz. The power efficiency of the proposed apparatus would be nearly 100 percent; the main insertion loss would be only about 2 dB and would be associated with fiber-optic input and output.

The apparatus would produce a constant frequency shift by exploiting the phase shift of the laser beam in an electro-optical medium. The effect, upon frequency, of a steadily increasing or decreasing phase shift is equivalent to the Doppler frequency shift produced by a steadily advancing or retreating mirror. Of course, there is no practical way to realize, in a compact apparatus, a steadily advancing or retreating mirror. Similarly, there is no practical way to realize its functional equivalent in a phase modulator in which the phase shift could be made to increase or decrease steadily without limit.

However, it is possible to drive two electro-optical modulators with identical sawtooth waveforms that differ in phase by about 180°. It is also possible to switch a laser beam electro-optically so that it repeatedly passes through one modulator and then the other. If this switching were done in proper synchronization with the sawtooth modulation waveform, then laser beam could be made to undergo either an increasing or a decreasing phase shift at all times. The proposed apparatus is based on this concept.

The apparatus (see figure) would be made from standard lithium niobate integrated optics. A Mach-Zehnder switch driven by a rectangular waveform synchronized with the sawtooth modulating waveform would direct the laser beam alternately along optical paths to two phase modulators. The amplitude of the sawtooth waveform would typically be chosen to obtain a peak-to-peak phase modulation of 4π radians. The shift in frequency of the laser beam would equal the phase-modulation rate, which would be proportional to the amplitude and repetition

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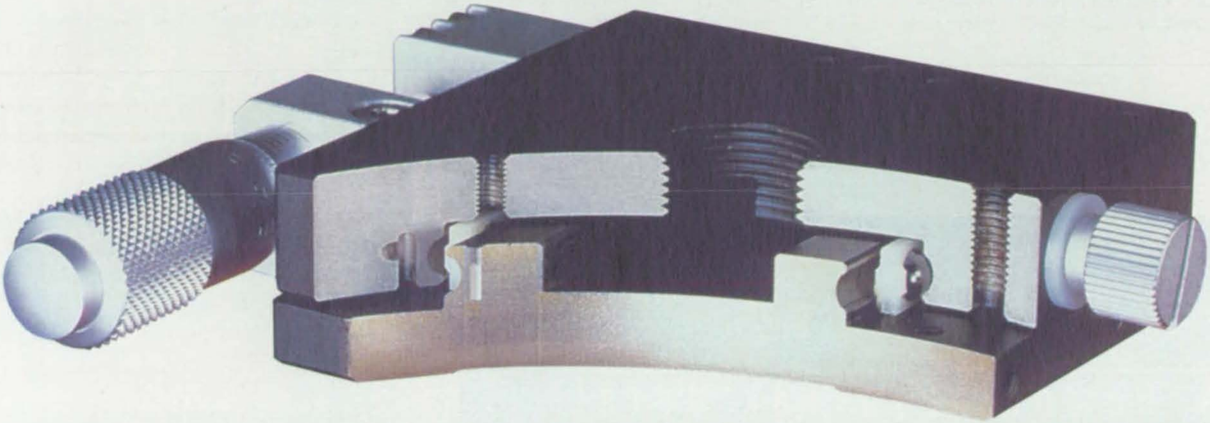

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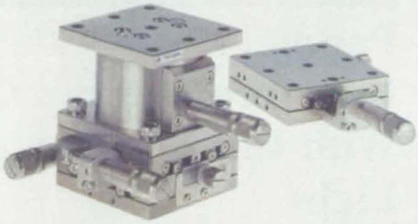

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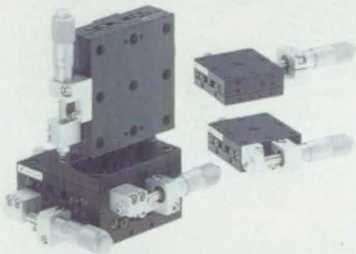

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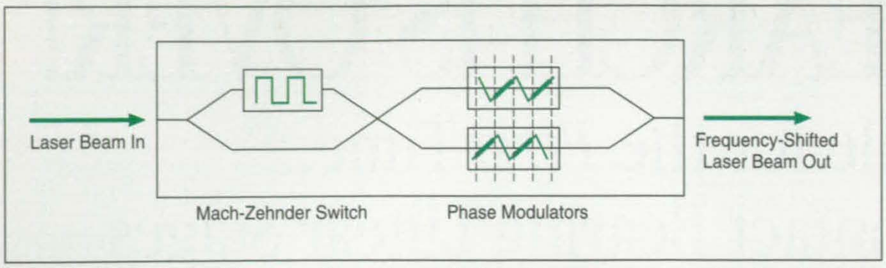

The **Switch Would Direct the Laser Beam** alternately through one phase modulator, then the other. The rectangular switching waveform would be synchronized so that at any given instant of time, the laser beam would be exposed to the rising edge (only) of the sawtooth modulating waveform.

frequency of the sawtooth waveform; for example, at a typical repetition frequency of 1 GHz, the frequency shift would be about 2 GHz.

The amplitude and phase relationships between the two sawtooth modulating waveforms would be chosen so that during the brief switching intervals in which parts of the laser power were passing partly through both phase modulators, the difference between the phase shifts produced by the two modulators would be 2π radians. This choice would ensure coherent addition of the outputs of the two modulators and prevent the introduction of a spurious phase modulation associated with the switching.

This work was done by Roman C. Gutierrez of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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Refer to NPO-20531, volume and number of this NASA Tech Briefs *issue, and the page number.*

Parallel-Beam Interferometry With Incoherent Light

It should be possible to achieve resolution beyond the diffraction limit.

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique of parallel-beam interferometry with spatially incoherent light has been proposed to solve two problems that arise in conjunction with using interferometry to measure the shape of a surface. The first problem is how to obtain spatial resolution in excess of the diffraction limit; the second problem is how to measure the variation in the shape of an object with temperature.

Figure 1 illustrates the principle of operation. Spatially incoherent light (e.g., light from an incandescent lamp) would be collimated, then made to pass through beam-splitting-and-combining optics that would split the light into two parallel beams aimed toward the object of interest. These optics would be adjustable to

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0.250mm thick Sapphire, Lambda Physik DPSSL-355 nm. Photo Courtesy of Laser Zentrum Hannover.

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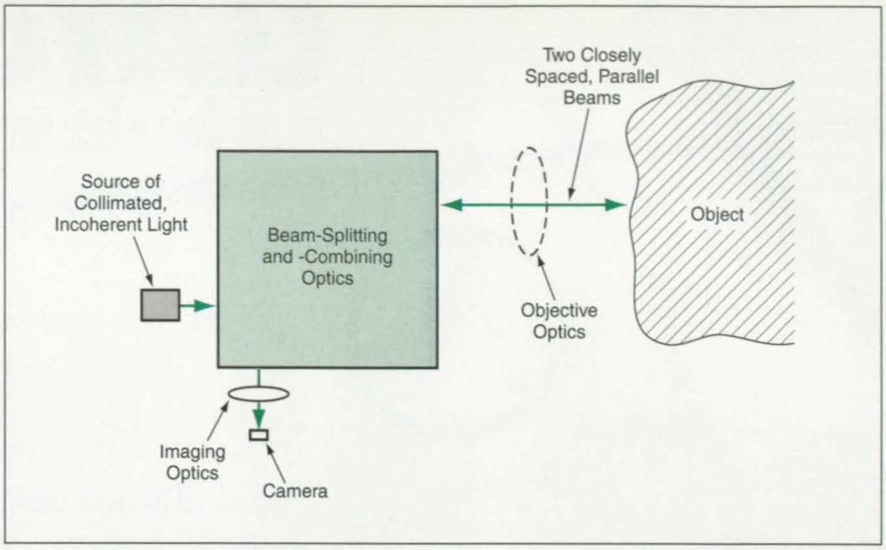

Figure 1. In **Parallel-Beam Interferometry**, an object would be illuminated with two closely spaced, parallel beams generated by splitting a single input beam. The distance between the parallel beams would be adjustable in any direction in the plane perpendicular to the axis of propagation.

change the distance between the two beams. The light reflected by the object would pass back through the beam-splitting-and-combining optics which combine the two beams back into a single beam, then through imaging optics into a camera. Objective optics may or may not be used, as explained below.

The technique can be characterized as one that utilizes speckle interferometry with a variable speckle. The splitting of the source incoherent beam into two parallel beams introduces a delta-function spatial coherence that gives rise to a speckle interference in the camera. The speckle pattern is measured as the distance between the two beams is changed. The change in distance changes the location of the delta function in the spatial coherence, and a spatial autocorrelation function is measured. The surface of the object of interest can be determined accurately from the autocorrelation function. Under ideal conditions, resolution beyond the diffraction limit can be achieved.

The solution to the second problem would have to involve utilization of the speckle interferometry in a way that would make it unnecessary to scan the beams. One such way would be to form more than one interference pattern by use of more than two beams, in a generalization of the basic concept that involves several two-beam interferometers working together.

Figure 2 presents an example of a parallel-beam interferometer according to the proposal. A collimated beam of light would pass through an assembly of beam splitters and prisms. The first beam splitter together with the second beam splitter would cause both beams to traverse the same path (and thus the same path

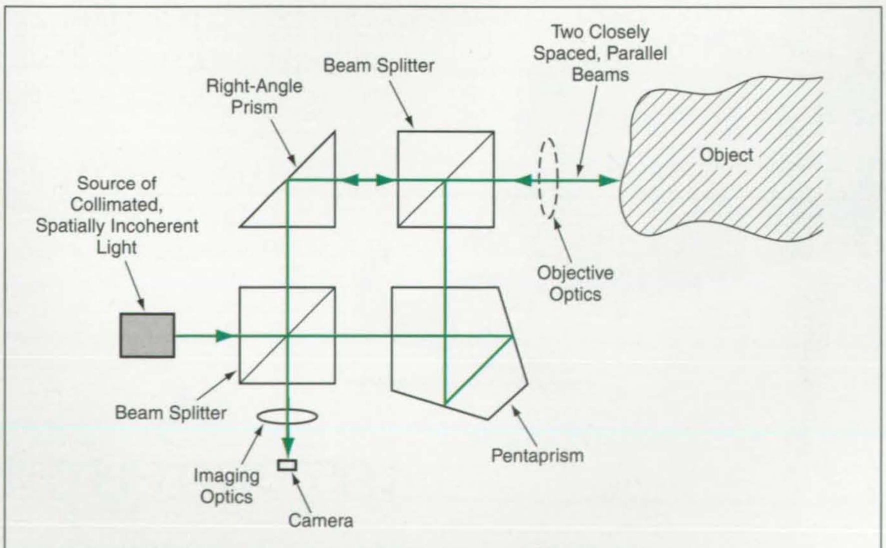

Figure 2. This **Optical Layout** is one of several candidate layouts for a practical parallel-beam interferometer. The two nonpolarizing beam splitters and the prism would be moved in coordination to adjust the distance between the parallel beams.

length) in opposite directions; this would ensure that white-light fringes would be imaged on the camera. The objective optics may or may not be used, depending on the required numerical aperture, which, in turn, would determine the diffraction-limited imaging resolution. The two beam splitters and the right-angle prism would be moved together to change the distance between the two beams without changing the difference between their optical-path lengths.

In addition to resolution beyond the diffraction limit, the proposed technique would afford several other advantages over prior interferometric imaging techniques:

1. The distance to the object could be set arbitrarily.
2. The alignment of the object with the interferometer would be simplified.
3. Because the two beams would be of the same magnitude, regardless of the reflectivity of the object, the visibility of the fringes would be relatively high.
4. Because the two beams would travel along nearly the same path, effects of variations in the index of refraction of air would be relatively small. Only high-frequency index variations like those associated with turbulence would be problematic.
5. Imaging could be done with very small numerical apertures, so that it would be possible to use working distance longer and optics smaller than those customarily used.

This work was done by Roman C. Gutierrez of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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Refer to NPO-20687, volume and number of this NASA Tech Briefs *issue, and the page number.*

Detecting Hydrazine via Optical Detection of Ammonia

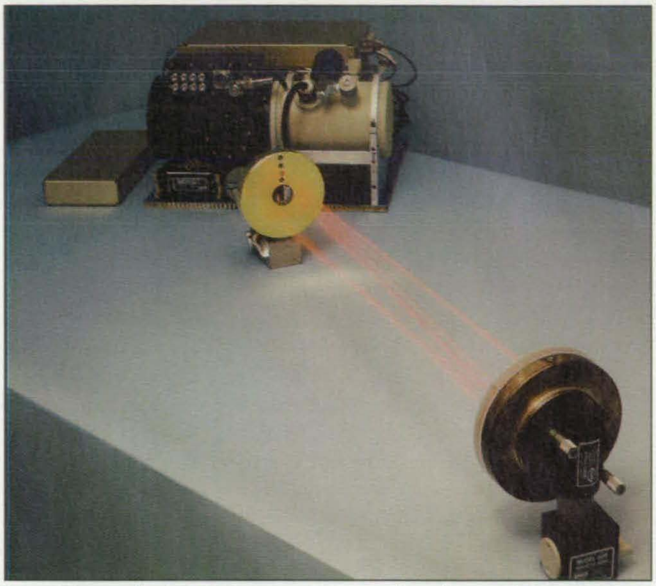
An ammonia signal would be indicative of hydrazine because hydrazine decomposes to ammonia.

NASA's Jet Propulsion Laboratory, Pasadena, California

In a proposed method for rapidly detecting hydrazine in air at concentrations at or above 10 parts per billion by volume (ppbv), tunable diode lasers (TDLs) and photodetectors would be used to measure infrared absorption spectra of both ammonia and hydrazine simultaneously. In this method, one would take advantage of the fact that (1) ammonia is formed in the decomposition of hydrazine and is always present when hydrazine is present and (2) the spectral features attributable to ammonia are much stronger than those attributable to hydrazine, and thus ammonia can be detected more easily. In a typical situation in which hydrazine is suspected of leaking and in which one could rule out an alternative source of ammonia (e.g., an open bottle of household ammonia solution or window cleaner), an ammonia spectrum could thus be taken as an indication of hydrazine.

This method could be implemented by a variety of TDL spectrometers. A typical instrument would include a sample cell, one end of which would be occupied by a sensor head containing two near-infrared TDL/photodetector pairs (one pair for hydrazine and one for ammonia) capable of operating at room temperature. A mirror or a retroreflector would also be included on the sensor head. A retroreflector would be mounted on the other end of the sample cell. The various optical components would be positioned and oriented to make each laser beam traverse the cell multiple times to obtain a total optical path length of 40 m. The instrument might resemble the one shown in the figure, which is a previously developed TDL spectrometer. On the basis of previous experience with TDL spectrometers, the proposed instrument could be expected to weigh 5 to 10 lb (≈2.3 to 4.5 kg).

The atmosphere to be sampled would be drawn through the sample cell, the interior of which would be maintained at a pressure of 0.1 atm (≈10 kPa). Extrapolation from experiments on similar instruments indicates that the proposed instrument could detect hydrazine in a concentration as low as 20 ppbv



Laser Beams of a TDL Spectrometer are reflected several times across a sample space. The proposed instrument could have a similar optical configuration and would utilize two laser beams: one for detecting hydrazine and one for detecting ammonia.

and ammonia in a concentration as low as 2 ppbv. Thus, although the instrument could not measure hydrazine concentrations below 20 ppbv, it could nevertheless give a warning that hydrazine is likely to be present.

This work was done by John Houseman, Chris Webster, Randy May, and Mark Anderson of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20680

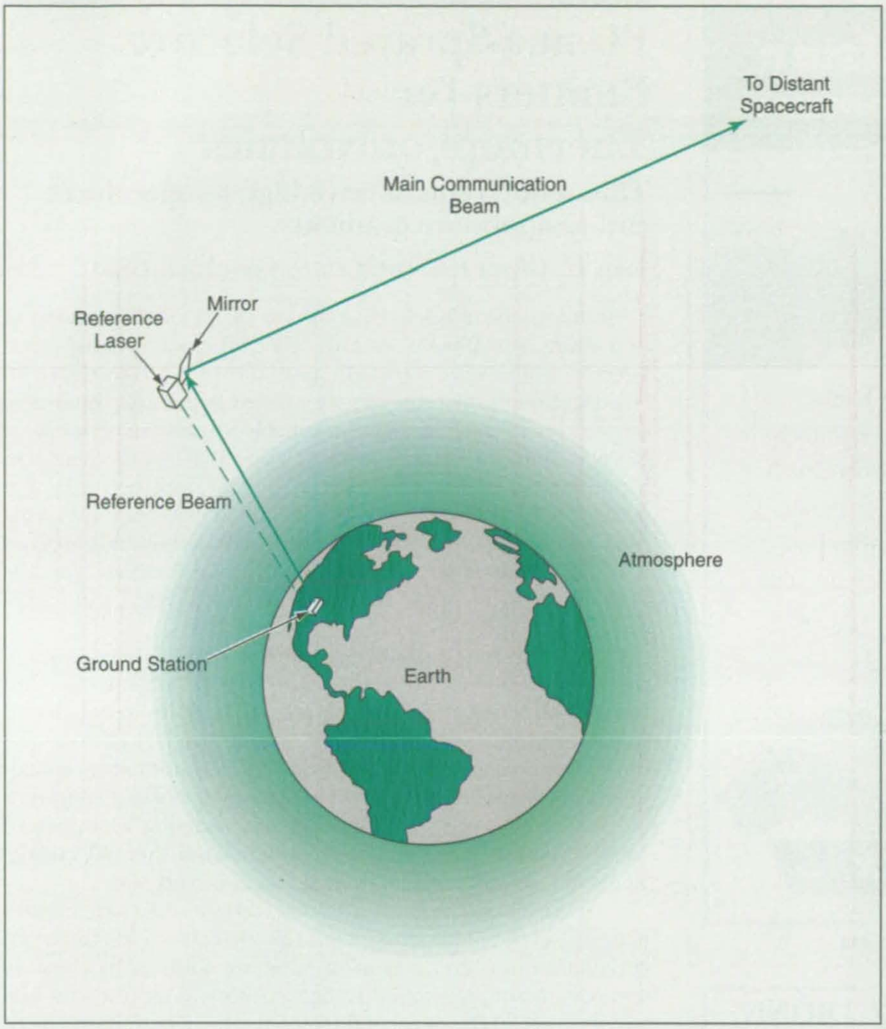
Correcting for Atmospheric Effects in Optical Communication

Distortions of a downward-propagating beam would be used to correct an upward-propagating beam.

NASA's Jet Propulsion Laboratory,
Pasadena, California

A method of correcting for the distorting effects of the atmosphere upon a laser beam used in free-space optical communication has been proposed. The original version of the method would be applied to a system in which a laser beam would be transmitted from a ground station to a precisely flat and precisely oriented mirror on a spacecraft in orbit around the Earth, then relayed to a distant spacecraft by reflection from the mirror (see figure). Because propagation of the beam in outer space would be distortionless, the method addresses only the distortions that would arise along the ground-station/near-Earth-spacecraft path.

In the original application, in order to send a sufficiently strong signal to the distant spacecraft, it would be necessary to deliver an approximately diffraction-limited, undistorted laser beam to the orbiting mirror for relay to the distant spacecraft. Therefore, at the ground station, adaptive optics would be used to apply compensatory predistortions to can-



Adaptive Optics at the Ground Station would compensate for atmospheric optical distortions. The information for controlling the adaptive optics would be obtained from measurements of the reference beam.

cel the optical distortions (tilt and scintillation) introduced by the atmosphere. The control signals for the adaptive optics would be generated as explained next.

A small laser aboard the near-Earth spacecraft would transmit a reference beam to the ground station. Because it would propagate along the same path as that of the main communication beam, the reference beam would undergo essentially the same distortions. Thus, measurement of the tilt and scintillation of the reference beam arriving at the ground station would provide the information needed to control the adaptive optics to apply the compensatory predistortions.

To compensate for the predictable aberration caused by orbital motion of the relay mirror, the reference laser would have to be offset from the relay mirror by an angle (as seen from the ground station) of $2v/c$ radians in the plane of relative motion, where v is the component of orbital velocity orthogonal to the optical path and c is the speed of light. For a typical orbit, the offset distance for this angle would be no more than about 8 m.

The reference beam arriving at the ground station must be bright enough that measurements and corrections can be completed within an interval of about 1 millisecond, which is dictated by the temporal variation of atmospheric optical distortion. This requirement turns out not to be especially severe: for example, it has been estimated that even during the day, the beam from a reference laser with a wavelength of 0.5 μm, a power of 1 mW, and optics with an aperture diameter of about 10 cm, located in a geosynchronous orbit, would be sufficiently bright for measurement through a ground telescope with an aperture diameter of about 1 m and a band-pass optical filter.

This work was done by John Armstrong, Cavour Yeh, and Keith Wilson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20506

Plasma-Sprayed Selective Emitters for Thermophotovoltaics

Thin oxide films survive high temperatures and temperature gradients.

John H. Glenn Research Center, Cleveland, Ohio

Plasma spraying has been shown to be an effective means of depositing thin films of various oxides for use as wavelength-selective emitters for thermophotovoltaic devices (see Figure 1). Wavelength-selective emitters are needed to increase the overall efficiencies of such devices. A suitable emitter material for a given thermophotovoltaic device is one that, when heated to incandescence, emits light with a spectral peak or peaks that preferably lie within the wavelength band of peak response of the photovoltaic cell in the device; more specifically, what is desired is low emissivity at photon energies less than the band gap and high emissivity at photon energies above the band gap of the photovoltaic cell.

Oxides that have shown promise as wavelength-selective-emitter materials include some rare-earth oxides (erbia, thulia, and holmia, both singly and in combination), plus cobalt-doped spinel. Previous techniques for fabricating emitters of these and other materials include casting from slurries and doping crystals with rare-earth oxides. The major disadvantage of cast emitters is mechanical weakness — especially the inability to withstand stresses caused by temperature gradients and thermal cycling. The major disadvantage of doped crystals is high cost.

To fabricate specimens for testing, the various oxide emitter materials were plasma-sprayed onto silicon carbide, alumina, and yttria substrates. Preparation of substrate surfaces by cleaning and roughening was found to be necessary to ensure adhesion and integrity of the deposited materials (see Figure 2). Some of the substrate surfaces were coated with reflective layers of refractory metals (platinum or rhodium) to suppress unwanted out-of-band radiation from the substrates. Emitter deposits with thicknesses from 15 to 250 µm were built up, a few microns per pass, by multiple passes of a plasma-spray apparatus.

The emitters (that is, the coated substrates) were tested in a bench-top thermophotovoltaic apparatus capable of reproducing prototypical operating conditions. The apparatus included an electrical heater for the emitter, and a 0.70-eV GaSb photo-

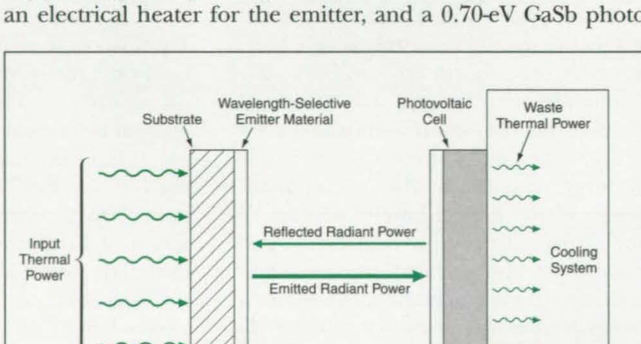


Figure 1. A **Thermophotovoltaic Device** is a thermal-to-electric power converter that includes a thermal emitter and a photovoltaic cell. A wavelength-selective emitter material and a short-wavelength-pass filter help to increase energy-conversion efficiency and reduce the cooling load for the cell.

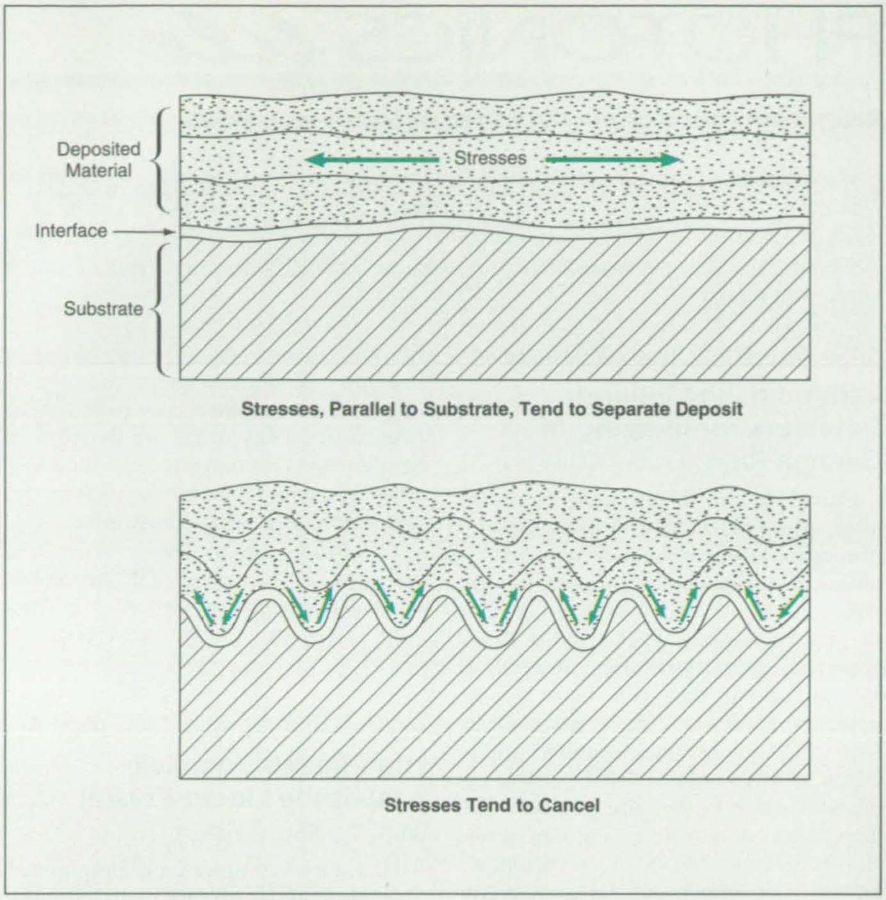


Figure 2. **Roughening the Substrate Surface** breaks up internal stresses, thereby helping to prevent delamination of the deposited material.

voltaic cell equipped with an integral filter. This apparatus was designed to enable the comparison of the cell output power, total power emitted, and conversion efficiency for various emitters under similar conditions.

In the tests, the plasma-sprayed emitter materials were found to retain their spectral emission characteristics through the deposition process. They were found to survive prototypical operating conditions, including temperatures up to 1,760 K and associated temperature gradients. The plasma-sprayed emitter materials did not exhibit any observable degradation during long-term operation at high temperature (3,600 hours at 1,500 K). Under the given test conditions, the best of the emitter materials tested was found to be a mixture of erbia and thulia; in comparison with a single oxide, the mixture provided stronger emission and hence more useful power within the wavelength band of the photovoltaic cell.

This work was done by Christopher J. Crowley and Nabil A. Elkouh of Creare, Inc., for **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16809.

PHOTONICS *file*

***Recent photonics briefs published in* NASA Tech Briefs**

Many photonics-related briefs from NASA's field center laboratories appear in *NASA Tech Briefs* rather than in the *Photonics Tech Briefs* supplement. Listed here are some from issues of *NASA Tech Briefs* just past, edited for brevity and indexed with reference to original publication and the availability of a Technical Support Package on *Photonics Tech Briefs'* web site.

NASA Tech Briefs June 2000, page 44

Cadmium Zinc Telluride Detectors for Imaging of Gamma Rays *(GSC-14044)*

Planar arrays of cadmium zinc telluride photodetectors with readout electronic circuitry have been developed for use as hard-x-ray and gamma-ray image sensors. When a coded x- and gamma-ray-opaque aperture mask is put in front of such a sensor, the resulting assembly is an instrument that can be used to observe hard-x-ray and gamma-ray sources. In the original intended application, the instrument will be operated in outer space to measure precisely the direction to distant sources of hard-x-ray and gamma-ray bursts of cosmological interest. A prototype of the instrument has also been used to image hard-x-ray and gamma-ray sources in a terrestrial laboratory setting.

For further information, access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Electronic Components and Systems category.*

NASA Tech Briefs May 2000, page 34

On-Chip Correction for Defective Pixels in an Image Sensor *(MSC-22827)*

A method of correcting for defective pixels in an integrated-circuit image sensor of the active-pixel sensor type has been proposed. The corrections would be made by additional readout circuitry on the image-sensor chips. By making it unnecessary to discard sensor chips that contain limited numbers of scattered defects, the method would increase effective production yields and thereby lower the cost of individual image sensors.

The coordinates of any defective pixels and of any defective rows or columns of pixels would be stored in several registers. These registers would function in the manner of a content-addressable memory. During readout, the current row and/or column address would be applied to this memory and a flag would be generated if the current address matched the stored address, signifying that the current pixel, row, or column is defective. A practical approach would involve replacing the output from a dead pixel with a copy of the output from a neighboring one that was read out previously. The copy could be obtained by use of a simple single-pixel delay line.

For further information, access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Electronic Components and Systems category.*

NASA Tech Briefs May 2000, page 47

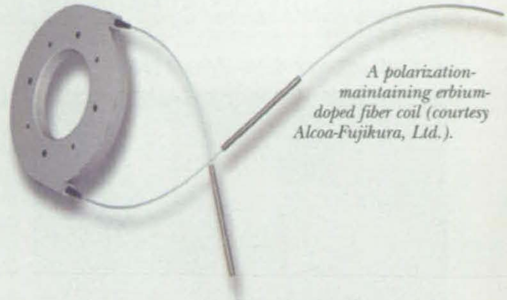
High-Speed Complex-Amplitude Liquid-Crystal SLMs *(MSC-22840)*

High-speed complex-amplitude spatial light modulators (SLMs) containing liquid crystals with pixel electronic circuitry on single-crystal-silicon backplanes are undergoing development. The basic approach taken in this project is to use fast-switching liquid-crystal materials and modulation-enhancing device geometries that have not been used in prior display systems. The modulator materials selected for this project are chiral smectic liquid-crystal (CSLC) materials of the high-tilt type. Overall, the project has been instrumental in increasing understanding of the principles of operation and of manufacturing liquid-crystal-on-silicon SLM products.

For further information, access the Technical Support Package (TSP) ***free on-line at www.ptbmagazine.com*** *under the Electronic Components and Systems category.*

Optics in the Southeast

When OPTO Southeast, a new SPIE regional conference, bows in Charlotte in September, it will focus interest on a high-tech corridor of burgeoning growth.



A polarization-maintaining erbium-doped fiber coil (courtesy Alcoa-Fujikura, Ltd.).

A high-technology corridor has emerged in the nation's Southeast, stretching from Virginia and the Research Triangle Park in eastern North Carolina to Atlanta in Georgia and Huntsville in Alabama. Farther south, optics is flourishing throughout Florida, with Orlando at the center of the activity.

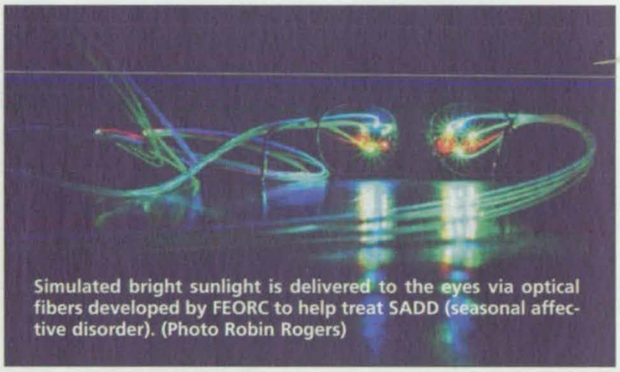
At the heart of this corridor is the city of Charlotte, NC. On September 18-19 optics professionals from the region will converge on the Charlotte Convention Center for the OPTO Southeast Conference, part of SPIE's series of regional conferences; it is also cosponsored by OSA and its Charlotte chapter. Technical presentations, short courses, and exhibits will be included, and Duke Energy will sponsor a keynote talk by Nobel laureate Nicolaas Bloembergen of Harvard University on "The Impact of Laser Applications on Our Lives."

Digital Optics Corporation (DOC) exemplifies the atmosphere of growth in the Charlotte region. A world leader in the design, manufacturing, and integration of micro-optical components and systems, DOC is one of the fastest-growing private companies in the U.S., placing at 120 on the *Inc.* 500 list last year. DOC recently broke ground on a 100,000-square-foot manufacturing and office facility in the university's Research Park near the University of North Carolina at Charlotte.

The Charlotte region is experiencing a convergence of fiber optic manufacturers around one of the heaviest sectors of fiber use: banking and finance, which are prominent among Charlotte's businesses. In nearby Spartansburg, SC, is one of the main facilities of Alcoa Fujikura Ltd. (AFL), which has experienced 16 years of rapid growth in the passive fiber optic product markets.

Corning Inc. recently completed construction of its advanced fiber manufacturing facility in Concord, NC, just outside Charlotte, and announced an expansion of its Concord and Wilmington, NC, facilities—what North Carolina's governor terms the largest single investment in the state's history. Corning's cable systems division, formerly Siecor, is based in Hickory, NC. Other companies with fiber operations in the Carolinas include Alcatel and Sumitomo Electric.

At the Cannon Research Center in the Carolinas Medical Center in Charlotte, near-field scanning optical microscopy is used for quality control in tissue engineering. Other work involves an optical biopsy for heart-disease diagnostics and treatment, and a means to cure patients with irregular heart rates using laser photocoagulation.



Simulated bright sunlight is delivered to the eyes via optical fibers developed by FEORC to help treat SADD (seasonal affective disorder). (Photo Robin Rogers)

Typical of startup medical optics companies in Charlotte is Medical Optical Imaging Inc., a small development company that opened its doors at the end of 1998. Pilot *in vivo* trials of its optical mammography device are currently in progress, and clinical trials aimed at FDA approval should start next year.

The region's industrial activity is complemented by a core of universities that have programs in optics-related disciplines. The University of North Carolina (UNC) at Charlotte offers numerous opportunities for optics-related study and research. Modern well-equipped laboratories, workshops, and clean-room facilities support optics research conducted by 15 faculty and their approximately 40 graduate students working toward MS and PhD degrees.

Just a short drive to the north, there is a broad range of optics research and education at Virginia Polytechnic Institute and State University (Virginia Tech) in Blacksburg, VA. The Fiber & Electro-Optics Research Center (FEORC) has an extensive research program in fibers, electro-optics, and thin-film materials. In addition to making fibers and nanostructured materials, FEORC is involved in fiber communications, sensing, and metrology applications.

The College of Engineering and Science at Clemson University, SC, recently established the Center for Optical Materials Science and Engineering, a research organization whose purpose is to foster multidisciplinary interactions and ease technology transfer to industry. In the Research Triangle Park, interdisciplinary optics-related activity finds strong backing at three major universities: Duke University, North Carolina State University, and UNC Chapel Hill. The Free Electron Laser Laboratory at Duke has UV and IR sources for research in basic physics, materials science, and the biological and biomedical sciences.

In Florida, the Orlando area is a hotbed of optics research and industrial growth. The Center for Research in Optics and Lasers (CREOL) at the University of Central Florida recently inaugurated a School of Optics, which offers PhD and MS degrees.

The Georgia Institute of Technology in Atlanta maintains strong optics research programs in both physics and engineering, and the University of Alabama at Huntsville is home to the Center for Applied Optics, which occupies a 110,000-square-foot optics building with about $6 million in state-of-the-art optics equipment.

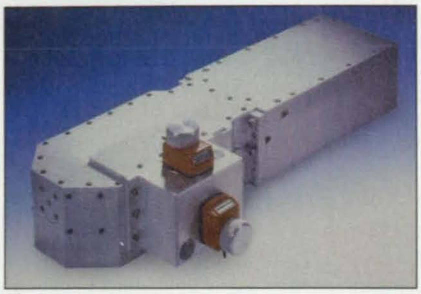
The universities in the region enjoy healthy collaboration with national laboratories. NASA's Marshall Space Flight Center(AL) and Langley Research Center(VA) have very active optical science programs. Other labs in the region include Oak Ridge National Laboratory and the Thomas Jefferson National Accelerator Facility.

For more information on OPTO Southeast, visit www.spie.org/info/se, or contact Bonnie Peterson at (360) 676-3290, ext. 406, or bonnie@spie.org.

New Products

For more information on the products below, go to www.ptbmagazine.com/products.

Product of the Month



High-Repetition-Rate DPSS Laser

Spectra-Physics, Mountain View, CA, introduces the BL6-355Q semiconductor-pumped solid-state laser, offering a combination of UV output power and repetition for industrial applications. According to the company, the Q-switched Nd:YVO_4 laser nominally delivers over 1 W of average power at 355 nm, at a repetition rate of 35 kHz. Among this laser's features are an LBO tripling crystal that can be translated to 77 different operating positions, eliminating crystal degradation as a lifetime-limiting factor. When crystal replacement is required, the tripling module can be exchanged in the field without optical realignment. Spectra-Physics' patented FC*bar*™ technology enables the pump laser to be mounted in the power supply and fiber-connected to the laser head. Both laser head and power supply are air-cooled.

Automatic Inspection System

As part of its optical solution offerings, Edmund Industrial Optics, Barrington, NJ, distributes the Eyebot™ Automatic Inspector for machine vision inspection systems. Eyebot features an operational mode that looks for the appearance or disappearance of shapes, while a separate mode learns and inspects over 100,000 colors, disregarding shapes. The system can be trained and used for object recognition or object inspection. The system also has the capacity to "learn" what an acceptable part is — a cumulative feature allowing the user to retrain the Eyebot until acceptable products pass inspection.

Alumina Ceramic Reflectors

Morgan Advanced Ceramics (MAC), Latrobe, PA, offers alumina ceramic reflectors designed primarily for use in pumping chambers for Nd:YAG lasers. The reflectors are manufactured from a high-purity formulation called Sintox AL, which has a highly diffuse reflection characteristic over a broad wavelength band, high mechanical strength, superior thermal conductivity, and excellent dimensional and electrical stability at all operating temperatures, according to the company.

Low-Power Multi-Channel Scaler

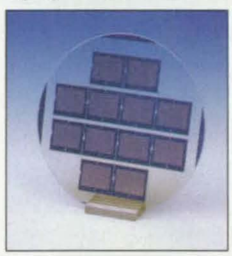
ASRC Aerospace Corp., Greenbelt, MD, has developed the AMCS-5 Advanced Multi-Channel Scaler card for lidar photon counting and range-resolving applications. Features include five simultaneous channels, 2.5 W power for all five channels, a small form factor, and flexibility to meet varied requirements. Multiple channels provide for the simultaneous collection of lidar data for different polarization and wavelength configurations. The card is available in a PC/104 form factor and can be stacked to provide multiples of five channels. The company says that most operational parameters are software programmable and further customization can be accommodated via reprogrammable hardware.

Handheld Radiometer

The handheld EFOS radiometer from EFOS, Mississauga, Ontario, Canada, is capable of measuring up to 225,000 mW/cm^2 of optical energy over the 250-600 nm band. The radiometer measures power or irradiance for illumination and nondestructive testing systems. The company says that a proprietary wideband detector system allows for the measurement range. User-changeable optical filters allow the unit to focus on specific bandwidths of sources producing a broad spectral output. The filter changes are made externally without having to open the unit.

High-Voltage Power Supply

Bertan High Voltage, Hicksville, NY, introduces the PMA series high-voltage power supply. The company says that this unit offers tight regulation across the full range of HV DC outputs and twice the power output, up to 8 W, with a volume reduction of 60%, and a 30% footprint reduction over the company's existing PMT line. Bertan says the PMA series fits OEM integration applications, including powering photomultiplier tubes, gamma detectors, and germanium detectors; biasing microchannel plates; or for system integration in mass spectrometry, cytometry, chromatography, or electrophoresis.

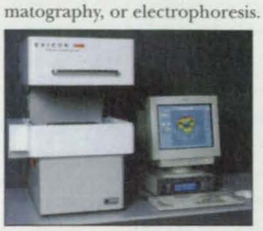


Optical Filter Arrays

Ocean Optics, Dunedin, FL, offers Dichroic Filter Arrays™ (DFA). The arrays combine optical thin-film deposition techniques with microlithographic procedures to deliver micron-scale precision patterning of dichroic coatings on a single substrate. This technology is utilized for dense wavelength division multiplexing applications requiring improved MEMS devices. It can also be used for dielectric multilayer reflectors, bandpass filters, dichroic edge filters, and broadband antireflection coatings.

Diode-Pumped Solid-State Laser

Cutting Edge Optronics, St. Charles, MO, expands its Stiletto laser line with the introduction of the S-Series laser systems. The company says that the S-Series family is a CW diode-pumped solid-state unit that will operate maintenance-free in the dirtiest industrial environments. The unit has multiple triggering options and field-replaceable components. It delivers up to 50 W CW or can be acousto-optically Q-switched from 1 to 50 kHz, delivering up to 35 W. Several models are available, including a TEM_{00} unit.



Birefringence Measuring System

Hinds Instruments, Hillsboro, OR, has developed the Exicor™ 150AT, a low-level birefringence measurement system that provides readings of birefringence magnitude and angle simultaneously. Exicor maps samples of various optical materials from the UV to the infrared and displays the data in high-content 2-D and 3-D birefringence images. It can measure the magnitude of retardation of linear birefringence with a sensitivity of +/-0.005 nm. The direction of birefringence is measured with an accuracy of less than 1° for retardance greater than 0.5 nm.

Laser Scan Bar-Code Reader

The BL-600 bar-code reader from Keyence Corp. of America, Woodcliff Lake, NJ, offers 1.6X the reading range and 2X the reading area of conventional readers according to the company. The reading angle is ±60°, and the unit reads bars as thin as 0.125 mm. Specular reflection cancellation (SRC) circuits eliminate reading errors caused by highly reflective backgrounds. The bar-code reader offers preventive maintenance information, which outputs diagnostic information during the reading process and enables the user to identify and classify problems that may lead to reading errors. A built-in test button activates a 5-bar reading efficiency display to help simplify setup and maintenance.

Diffuse Laser Sensor

The OHDK 10 diffuse background-suppression laser sensor from Baumer Electric, Southington, CT, measures 10 by 27 by 16.3 mm and has a sensing range of 20 to 100 mm, adjustable with the turn of a screwdriver. The sensor, which the company calls the smallest in the world, utilizes true background suppression by triangulation. It allows detection regardless of color, texture, or reflectivity while simultaneously ignoring all background objects by mechanically adjusting the receiver's lens to sense a target at a specific point in space. A diode laser produces a pinpoint light spot of less than 0.2 mm at 40 mm from the sensor. It has a wide 10-30 VDC supply range demanding less than 50 mA supply current.

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FREE NEWSLETTER

System Allows Remote Control of Launch Pad Data Acquisition

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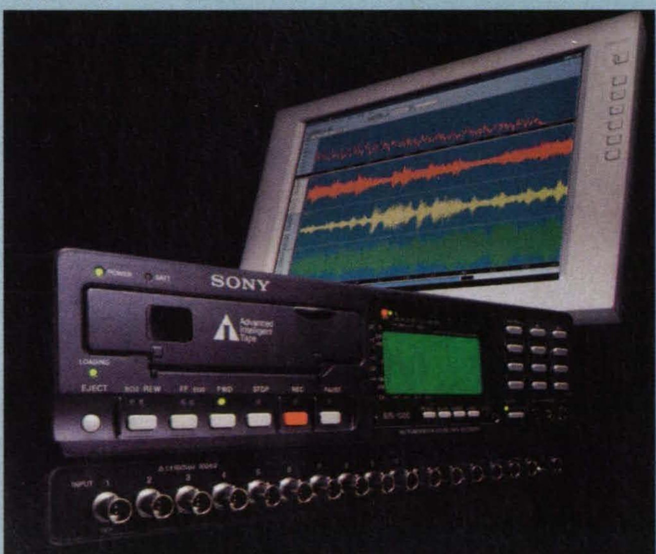
Some applications requiring data acquisition — such as the launch of space vehicles — are potentially hazardous to Ground Support Equipment (GSE), structures within 300 feet of the launch pad, and nearby personnel. Consequently, remote operation is essential. Today, it is possible to remotely collect high-fidelity data of a wide range of bandwidths (to 160 kHz) for long periods of time with instrumentation data recorders connected to a network or Internet.

Launch of a Space Shuttle exposes GSE and nearby structures to intense vibration due to acoustic pressure loads generated by rocket exhausts. Continuous monitoring of launch-critical loads (acoustics) and structural response (vibration and strain) is vital for ensuring operational safety and long-term reliability of launch pad structures.



Data gathered from field tests is the only practical avenue for accurate vibroacoustics analysis. This has resulted in decade-long research at NASA's Kennedy Space Center (KSC) in Florida that is focused on field measurements and the subsequent characterization of launch acoustic loads.

To make the required measurements, a unique test system has been configured that consists of a specially made verification test article (VETA) mounted on the launch pad at approximately main-engine level at Pad 39A. Depending upon the particular tests, a variety of sensors is attached to the structure. Microphones also are deployed in the area around the pad. The sensor wires are shielded from the intense liftoff heat and RFI/EMI as they pass through the pad base and into the blockhouse below. Sensor leads are connected to either signal conditioners whose output feeds a data recorder, or directly to the data recorder, depending upon the sensor type.

The data recorder at the launch pad is connected to a host PC control system via the PCIF250 I/F (16-bit parallel for data and RS-232C for control), a Sony packaged PC-based data transfer system. The PC, which has a high-speed modem, Ethernet, and Intranet connections, runs a special version of Sony's PCscanII recorder control and data acquisition package. All of the data acquisition instrumentation is located in an equipment-safe computer room 100 feet below the launch pad. A second computer system with modem, web, and Intranet connections running PCscanII software for TCP/IP data exchange/analysis, resides in a KSC facility located approximately 10 miles from the launch pad. This unique setup provides for accurate monitoring of the vibration data from the VETA, and total remote control of the data acquisition process at the launch pad site.

The data acquisition system (DAS) is a unique solution used to monitor and record launch data. Composition of the system was influenced by technical, cost, operation, and management considerations, including:

- Low initial/maintenance/operational costs
- Remote data acquisition, control, and data transfer
- Timer control for night launches
- Capability to control multiple recorders
- Capability for real-time data monitoring
- Instant data accessibility after launch
- Integration into and use of existing data
- Rugged, flexible, and transportable, with upgrade potential.

To accurately assess the Space Shuttle vibroacoustic environment, a DAS system that was able to sample data at a high sampling rate (12 ksamples/sec for each of the 16 data channels), had high dynamic range (84 dBs), high amplitude sensitivity (16 bit A/D and D/A), and low phase shift between channels (2 degrees or less) was essential. PCscanII software enabled data transfer from the recorder to the PC for display and analysis.

The VETA approach represented the first comprehensive effort to install a safe structure, install it within the launch pad perimeter, and measure acoustic and vibration response data simultaneously. It was important to install the VETA in such a manner as to expose it to both direct and reflected acoustics.

Prior to launch, all system equipment is powered up and Windows is started on the PCs in the blockhouse and at the off-pad facility. The PCscanII software is started on the pad PC. All sensors, signal conditioners, the data recorders, and PC systems are checked thoroughly, with proper operation confirmed. Once the pad is closed for launch, there is no way to get back into the blockhouse to change the setup.

The off-pad facility computer connects to the pad PC using modem and remote PC control software, allowing those away from the pad to monitor the PCscanII software and, therefore, the data acquisition process on the pad PC.

As the launch begins, engineers can observe the real-time data from the sensors on the test structure and microphones nearby. Data acquisition to the pad PC hard drive can be controlled as needed. Engineers also can see a good selection of live basic time and frequency domain data for any channel.

Data collected on the pad PC can be transferred to the off-pad facility PC in semi-real-time using the remote TCP/IP interface software. The data collected and the resultant analysis is used for reporting on a wide range of environmental, structural damage, and other important aspects involving acoustics, shock, and vibration.

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Commercialization Opportunities

Inexpensive, Rugged Oxygen Sensors Qualified for Flight

A relatively inexpensive commercial off-the-shelf oxygen sensor has been ruggedized and qualified to check for hazards associated with flight tests of propulsion systems supplemented by oxidizers.
(See page 32.)

Improved Eye-Tracking Apparatus

Improvements have been made in a commercial eye-tracking apparatus to make it less susceptible to error from ambient infrared light. The apparatus is intended for use as a computer interface for a person who is unable to use a keyboard.
(See page 44.)

Miniature Birefringence-Measuring System

A system, developed for investigating extensional flows of non-Newtonian polymers in microgravity, can be used on Earth to perform optical-retardation and dichroism measurements, to measure stresses with high sensitivity, to characterize polymers, and to measure orientation angles of molecular chains.
(See page 48.)

Extended Shelf Life for PMR Polyimide Resins and Prepregs

By retarding imidization, an improved class of formulations increases both shelf life and the upper limit of allowable temperature for handling and storage prior to final polymerization.
(See page 52.)

Magnetic Couplings for Gas-Driven Catapults

The proposed method can be applied to gas guns in diverse applications, including launching of spacecraft or aircraft, propelling various objects at high speeds along the ground, and accelerating objects to high speeds for research on hypervelocity impacts.
(See page 56.)

Systems for Dynamic Control of Growth of Protein Crystals

By use of this apparatus, one can monitor and control several parameters that affect the growth of protein crystals. These parameters include temperature, pH, ionic strength, concentration of solute, rate of change of concentration of solute, and possibly other parameters.
(See page 62.)

In Situ Activation of Microencapsulated Drugs

The proposed method would be suited for drugs that have short shelf lives in their active forms and/or could be activated at target sites upon exposure to nonharmful activation energy. The activating energy could be delivered via transducer externally or internally by use of a catheter.
(See page 64.)

Standard Wireless Protocols Create New Sensor Networks

The advent of the Bluetooth wireless protocol has created the platform for a wireless sensor architecture that ties the analog world to the Internet, reducing the cost, time, materials, and risk of wired sensor systems.

The use of sensors to collect data, monitor equipment, and transmit information is expanding into new industrial, commercial, and personal applications. Communications with sensors generally require wired links between a sensing element and data acquisition/ control electronics. The wiring process is often expensive, time-consuming, fault-prone, and potentially dangerous.

In the majority of these applications, each sensor must be wired individually to a data monitoring, data acquisition, or control device. Regardless of whether the device is intelligent, such as a workstation or a data storage box, wiring sensors is tedious. It usually is completed by test engineers or lab technicians with more important jobs or tasks. In addition to the wasted resources, often the wiring is temporary, and reconfiguration is required for different tests. Then, add the cost of the cables and the potential for damage or faults. And even when the wired process is simple, quick, and correct, wiring inadvertently can act as an antenna to distort incoming data.

These challenges have led to some initial experiments with unwired sensor solutions using frequencies in the industrial, scientific, and medical bands. There have been some successes in reducing faults and reconfigurations.

Enter Bluetooth

These first wireless efforts have used proprietary communications protocols. Without standardization and because each sensor requires its own transmitter, costs of implementation tend to be high — from $100 to as much as several thousand per transmitter. Also, compatibility between and among components of a wireless sensor solution remains low.

Now, with the advent of the Bluetooth wireless protocol — which uses the unlicensed 2.4-GHz radio frequency spectrum — cables can be replaced with a single, standard wireless connection. Bluetooth makes possible a sensor "network" that quickly can access data and respond to changing environmental conditions or process variables. Bluetooth is ideal for this kind of sensor network because it also includes provisions for security, and supports a high level of data transmission verification.

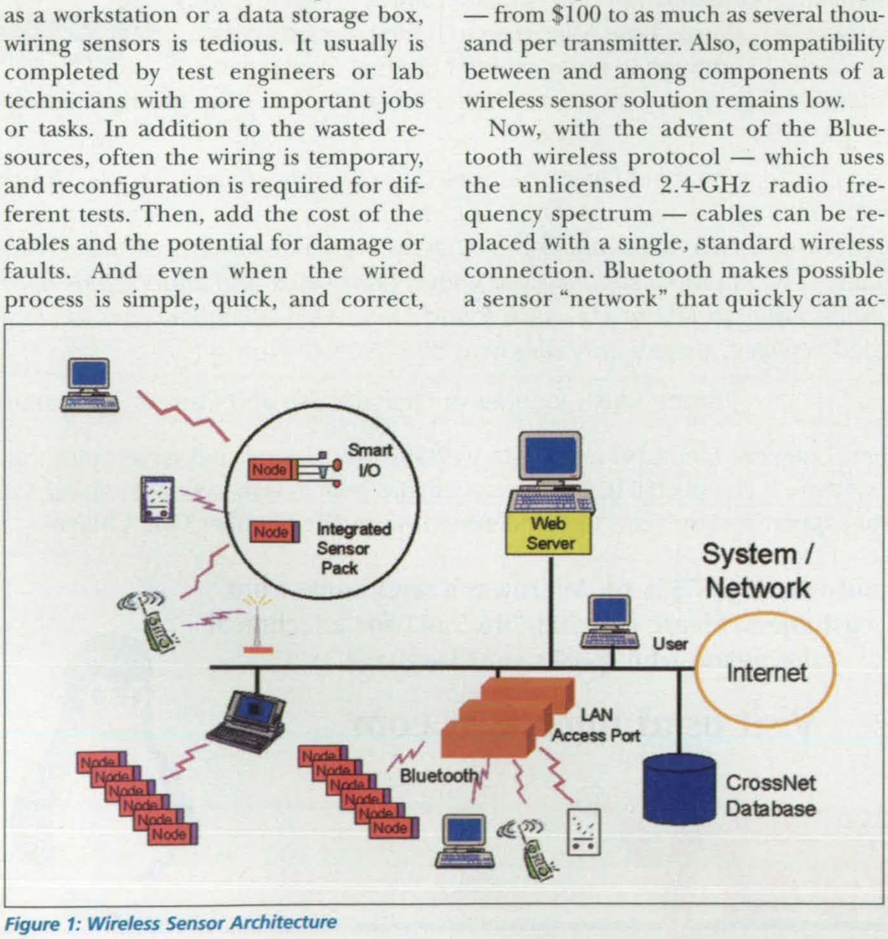


Figure 1: Wireless Sensor Architecture

Bluetooth can replace RS-232, parallel, Universal Serial Bus, and other standard cables with a single standard wireless link. It is being designed into a new generation of handheld computers, mobile phones, PCs, and Internet appliances that act as hubs for the wireless sensor network. Initially, Bluetooth supports a 10-meter transmission range, but is designed with higher power ratios so transmission ranges can be expanded to 100 meters as the specification evolves.

The combination of the Bluetooth standard with established sensor ID standards such as IEEE 1451 enables the creation of a reliable, lower-cost architecture with a broad range of applications. These include wireless data acquisition, machine and building monitoring and maintenance, medical and consumer product monitoring, and potentially many others. Benefits include reduced installation cost, the ability to rapidly reconfigure the data acquisition and control systems, and straightforward connection of measurement/control data to the Internet.

In order to succeed, a wireless system requires that external receivers be highly integrated, thus reducing or eliminating the expense of wireless modems and RF transmission products. A wireless sensor network has been developed using three basic building blocks: sensors, nodes, and hubs. All must be selected and configured to meet specific application requirements in a flexible network that supports data monitoring applications in which sensors transmit data via the node to a single computer or handheld display, either of which acts as the hub. Hubs can

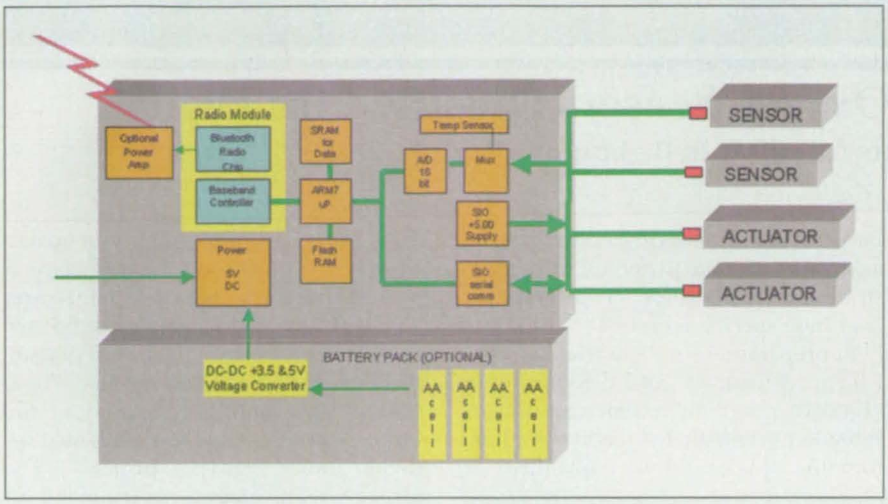


Figure 2: Node Architecture

range in complexity from single computers or handheld devices logging and/or displaying the data to web servers communicating using TCP/IP Internet communications protocol for wide area networking. Hubs also can connect using the TCP/IP protocol to other wired or wireless network architectures including Ethernet, LonWorks, and other protocols.

This hub also can be connected to the Internet so multiple users can access data remotely; more extensive sensor networks also can be created in which hundreds of sensors are connected via multiple hubs to the central network.

The architecture supports a broad range of sensor types through a smart interface: the SI/O. The SI/O connects the sensor to the node. It contains signal conditioning circuitry and the Transducer Electronic Data Sheet (TEDS), which is defined in the IEEE-1451.2 standard and allows sensors to self-identify and act interchangeably in networked systems. With this information, the hub can recognize a temperature sensor, pressure sensor, or other sensor type along with the measurement range and scaling information based on the information contained in the TEDS. Application software running on the host system (hub) then displays the data in a user-defined format or links the data to a number of popular Windows-based data acquisition and control software packages such as LabVIEW™ or Excel. Application software for PC environments as well as PDAs will be available.

In a typical application, the user mounts sensors on a machine, test stand, or in a facility at any number of points to be monitored. The individual sensors are then connected to an SI/O, which is attached to a channel on a node. Each node supports up to four channels of analog or digital inputs and outputs, and incorporates a Bluetooth radio for wireless communication with the hub. The node also can supply 5V excitation to each sensor or external sensor excitation as required. The sensor signal is then digitized (16-bit A/D resolution) for transmission to the hub.

Real-World Applications

Applications include data acquisition and control, environmental and building monitoring, HVAC diagnostics, automotive diagnostics, home networking and automation, and a host of situations where the wireless extension of the Internet to real-world data is of value. In some applications, the wireless access to the data is used to supplement the installed, wired control system in order for engineers and technicians to monitor machine status on demand.

The advent of Bluetooth has created the platform for a wireless sensor architecture that ties the analog world to the Internet, reducing the cost, time, materials, and risk of wired sensor systems for an almost unlimited set of industrial and commercial applications.

For more information contact the author, Michael Horton, CEO, of Crossbow Technology, 41 E. Daggett Drive, San Jose, CA 95134; Tel: 408-965-3301; e-mail: mhorton@xbow.com; or visit the web site at www.xbow.com.

Special Coverage: Sensors

Inexpensive, Rugged Oxygen Sensors Qualified for Flight

These sensors satisfy requirements for safety in flight tests.

Dryden Flight Research Center, Edwards, California

NASA Dryden Flight Research Center has ruggedized and qualified an inexpensive commercial off-the-shelf (COTS) oxygen sensor that accurately and reliably aids assessment, in flight tests, of the hazards associated with propulsion systems supplemented by oxidizers. Future flight-test vehicles continue to rely on such energetic propellants as liquid and/or gaseous oxygen and hydrogen for purposes of demonstration because these propellants deliver high specific impulses.

In preparation for flight testing in the Linear Aerospike SR-71 Experiment (LASRE) program, commercial sensors intended originally for medical and automotive application were qualified for flight. After a rigorous process of qualification and calibration, the sensors proved extremely reliable and repeatable, and gave engineers the confidence they needed to assess the hazard of flammability during test operations. These sensors have now been added to the Hyper-X program and are scheduled for use in future flight-test projects. (The Hyper-X is a proposed experimental hydrogen-fueled hypersonic aircraft.)

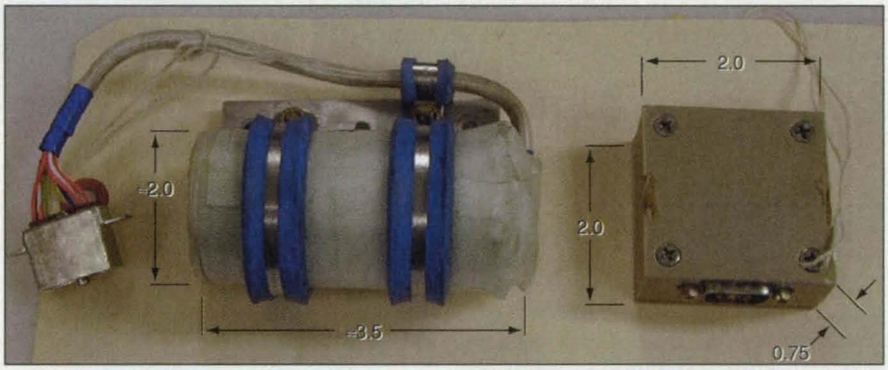


Figure 1. An **Oxygen Sensor and Its Temperature Controller** were electrically connected and packaged separately.

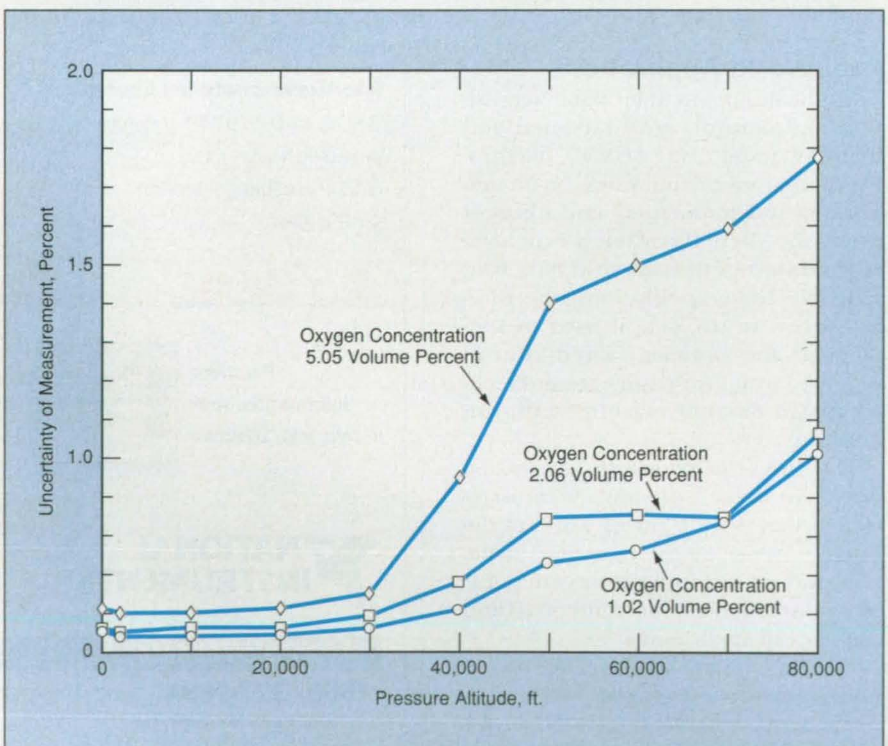


Figure 2. The **Uncertainty of Measurement** as a function of pressure altitude was computed for various concentrations of oxygen for a 99-percent confidence level after correction.

The sensor in question is a commercial-grade miniature fuel cell — in other words, a small transducer that converts chemical energy into electrical energy. Like all electrochemical transducers, a sensor of this type contains an anode, a cathode, and an electrolyte. At the cathode, during operation, oxygen molecules are reduced to hydroxyl ions. The anode is made of lead; during operation, lead in the anode becomes oxidized to lead oxide, producing two electrons for each atom of lead thus consumed. This particular transducer has cross-sensitivity only to other gases (e.g., halogens) that oxidize leads.

The sensor life expectancy has been estimated by the vendor to be approximately 2.4 years. However, because of the criticality of these sensors, it was decided that in the LASRE project, each such sensor will be replaced when its response deteriorates or it reaches a calendar life of 1.5 years.

In the laboratory calibration tests, the sensor was actively maintained at a temperature ≈115 °F (≈46 °C) to prevent freezing of the electrolyte (which is aqueous) as well as to maintain constant performance of the transducers throughout the flight envelope. Each sensor was inserted into an aluminum tube shell for structural support. Attached to the shell was a thin-film resistive heating element, a power transistor, and two resistance temperature devices (RTDs). In addition, thermal-insulation material was wrapped around the shell. The power to the heating element was regulated by a heater-controller circuit in a box separate from the sensor (see Figure 1), in response to temperature feedback from the first RTD. The second

RTD was used for monitoring and to provide a temperature reading as part of the sensor output.

At the initial application of power, the heating element was activated until the transducer assembly reached the set temperature. Once the set temperature was reached, the power to the heating element was cycled on the basis of the reading of the first RTD. During application of power to the heating element, the heater controller draws an electrical current <1/2 A.

In initial flight tests, it was found that two-point calibrations were not satisfactory for the use of these instruments in flight tests. A calibration test was designed to enable the attainment of the following three test objectives: (1) characterize sensor behavior with increasing altitude (decreasing partial pressure), (2) perform a statistical analysis of laboratory-test results (which analysis would give a quantitative measure of the level of confidence in the mean of the untested sensors), and (3) quantify the uncertainty of the sensor measurements with decreasing partial pressure. Several of the sensors were installed in a small test chamber and exposed to the following range of O_2 concentrations (volume percentages) with nitrogen balances: 0, 1.02, 2.06, 5.05, 10, and 21. Each sensor was cycled through a range of pressure altitude from sea level up to 80 kft (24 km) and then back down to sea level. During this cycle, the sensor output was measured at intervals of 10 kft (3 km), using the concentrations listed above.

Because of a nonlinear response that occurred during operation above 30 kft (9 km), an altitude correction factor was devised. This correction factor was computed in the following procedure: The ratio between (1) the true partial pressure of oxygen (as determined by use of the calibration gases) and (2) the transducer output was determined for each altitude. This ratio was then plotted against altitude, and the data of this plot were fitted with a fifth-order curve. During the flights, the correction factor was computed from the fifth-order curve. This correction factor was then multiplied with the linearly calibrated transducer output to produce an altitude-corrected partial-pressure reading. Normalization of this value by the static-pressure measurement yielded an output volume fraction. On the basis of the *t* distribution of the corrected readings, the uncertainty was found to remain less than one percent for altitudes less than 60 kft (18 km), as shown in Figure 2.

Twelve of the sensors and their respective thermal controllers were integrated into the LASRE flight-test fixture and were flight-tested out to a speed of mach 1.6 and an altitude of 52 kft (16 km). Eight of the original twelve sensors remained on board after removal of the LASRE for some follow-on flight tests at speeds up to mach 3.03, altitudes to 73 kft (22 km), and exposure to internal temperatures >130 °F (>54 °C). Even though the temperatures rose above the temperature-controller limits and the manufacturer's specifications for operation, the oxygen sensors exhibited no significant drift.

Four sensor suites are to be incorporated into the Hyper-X airplane for safety during the flight test in which the Hyper-X will be carried by a B-52 airplane. These sensors will be used to verify the desired and expected chemical inertness (more specifically, the lack of oxidizing gas) in the interior of the vehicle. They are being calibrated in much the same manner as in the LASRE program, but dynamic-response and sensor-recovery tests will be performed in addition, for comparison with results of tests in the boost and free phases of the flight of the Hyper-X.

This work was done by Neal Hass, Michele Jarvis, and Kim Ennix of **Dryden Flight Research Center**.

DRC-00-04

Array of Microscale Heaters and Heat-Flux Sensors

Heat transfer in boiling can be measured with unprecedented spatial and temporal resolution.

John H. Glenn Research Center, Cleveland, Ohio

A device has been developed for measuring heat-transfer rates at many points underneath individual bubbles during boiling, in order to determine the heat-transfer coefficient as a function of position and time. The device is a planar array of small heaters that also serve as heat-flux sensors.

Heretofore, the majority of experimental data on heat transfer in boiling have been obtained by use of devices as large as or larger than bubbles; consequently, the data have not been spatially resolved to dimensions smaller than those of bubbles, and little has been learned about local heat-transfer rates from wall surfaces under and around the bubbles as the bubbles grow and depart from the walls. The present device enables measurement of the local heat transfer from a wall surface during the growth and departure of a bubble, with very high temporal and spatial resolution. Thus, the present device is expected to contribute to better understanding of boiling heat-transfer mechanisms by indicating when and where in the bubble-departure cycle large amounts of heat are transferred from the wall. The information provided by this device could be used to validate or improve analytical and numerical models used in computational simulations of boiling. Other uses for temporally and spatially resolved heat-transfer data obtained by use of this device and similar devices include identification of time-varying structures in near-wall regions of turbulent boundary layers or impinging jets, study of heat-transfer coefficients associated with spray cooling processes, and determining shear stresses in turbulent flows.

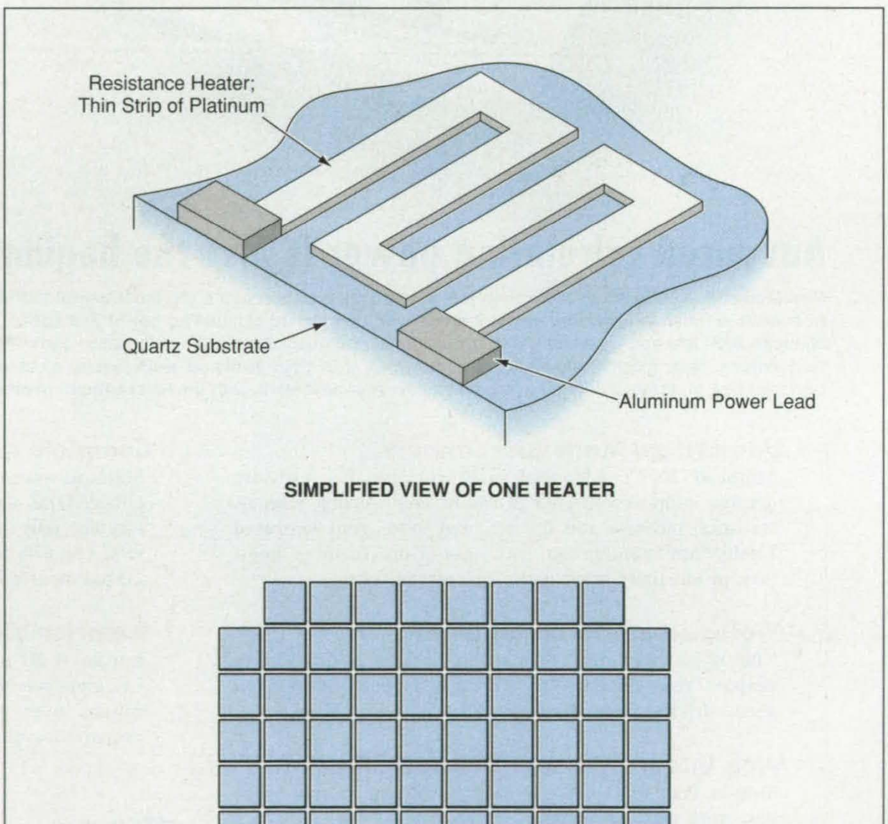
The device (see figure) includes a quartz substrate that supports a square array of 96 electrical-resistance heaters. Each heater occupies an area of 250 by 250 μm. The resistive heating element in each heater is a platinum strip 5 μm wide, 0.4 μm thick, and 6 mm in total length; the lateral gap between adjacent parallel portions of the strip is 5 μm. Each strip has an electrical resistance of ≈1 kΩ with a temperature coefficient of resistance of 2×10^{-3} °C^{-1}. Heater power is supplied through aluminum lines routed between the heaters to the edge of the array.

Each heater strip is electrically connected to one of the resistances in a Wheatstone bridge. The resistance (and thus the temperature) of the bridge is kept at a constant desired value by use of a feedback control circuit similar to circuits used in hot-wire anemometry: The circuit constantly adjusts the power supplied to the heater to keep the Wheatstone bridge balanced. Thus, the instantaneous power supplied to the heater is a measure of the local heat-transfer coefficient in that it equals the rate at which heat must be supplied to keep the affected portion of the surface at the desired temperature (e.g., the temperature of the wall in contact with the boiling liquid).

Because the heater strip is so thin, the frequency response of the heater greatly exceeds typical frequencies associated with boiling, making it possible to measure heat-transfer coefficients with high temporal resolution. The spatial resolution is, of course, determined by the pitch of the array.

This work was done by Jungho Kim formerly of the University of Denver and Richard Quine of the University of Denver for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16825.



Ninety-Six Thin-Film Electrical-Resistance Heaters in a square array are kept at constant electrical resistance and thus constant temperature. The instantaneous power supplied to each heater is a measure of the instantaneous local heat-transfer coefficient.

System Computes Flow Quantities From Acoustic-Sensor Output

Statistical and neural-network analyses yield information on single- or two-phase flow.

Stennis Space Center, Mississippi

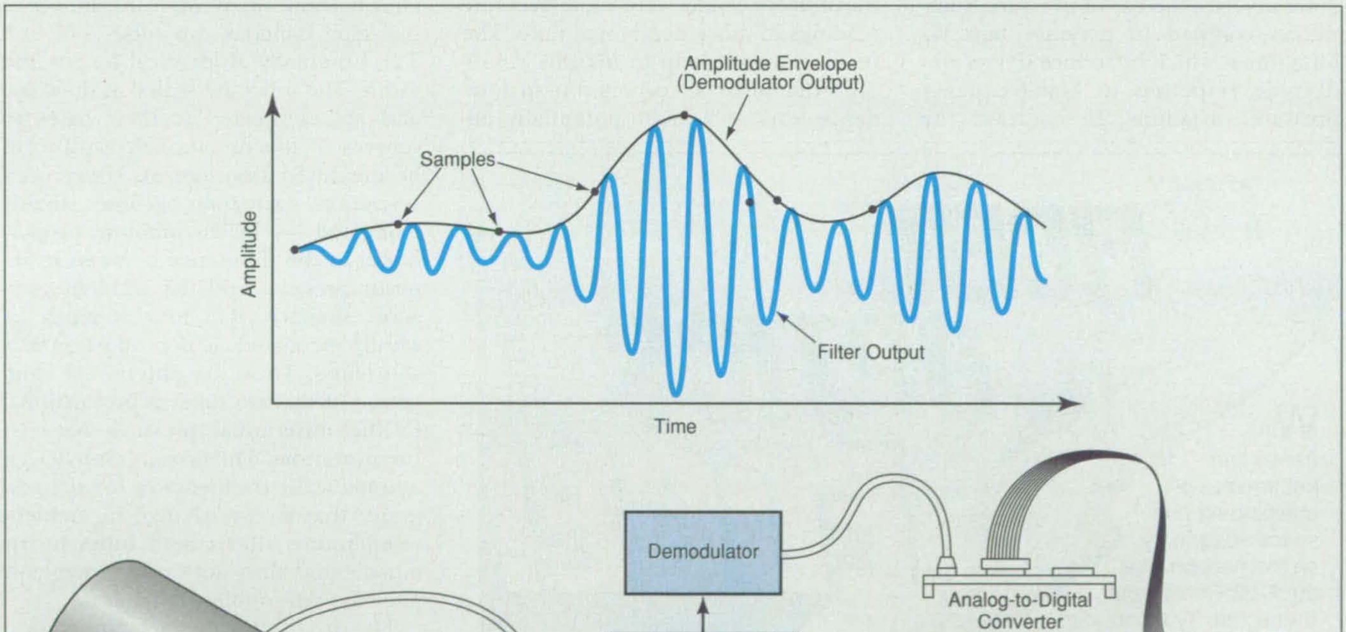
The figure schematically depicts a flow-measurement system based on an acoustic sensor mounted on a pipe, along which flows a single or two-phase fluid. The electrical output of the sensor is processed by an electronic subsystem to estimate various parameters of the flow.

The sensor output is first amplified, then sent through a narrow-band-pass filter with a pass frequency approximately equal to the resonance frequency of the sensor. (A typical acoustic flow sensor has a resonance frequency ≈83 kHz). For the purpose of digital processing to completely characterize the filtered signal, it would ordinarily be necessary to sample and process the signal at a rate of about four times the pass frequency. However, assuming that the sensor resonance is not highly damped, useful data about the acoustic excitation (and thus about the flow that causes the acoustic excitation) can be extracted by measuring the relatively slowly varying amplitude envelope of the filter output.

Accordingly, the output of the filter is demodulated to obtain the amplitude envelope. Because of the relatively slow variation of the amplitude envelope, it is possible to extract sufficient information by digitizing and processing the output of the demodulator at a lower sampling rate (as low as about 33 kHz), which can be implemented much more easily. The digital samples are fed to a computer, which executes special-purpose software to perform a combination of statistical and neural-network processing to obtain flow parameters. The sampling rate is low enough to enable the computer to process the samples in real time.

The statistical flow-indicator quantities calculated by the computer can include the following:

- The average and the standard deviation of the signal amplitude,
- The characteristic autocorrelation time of the variation in the amplitude envelope,
- The average of the absolute value of the difference between successive samples,
- The root mean square of the difference between successive samples,
- The average and the root mean square of the interval between instants when the instantaneous amplitude crosses from below to above the average amplitude, and
- The average and the root mean square of the time between an upward and a downward crossing.



Analog and Digital Electronic Circuits process the output of an acoustic sensor on a pipe. Flow parameters are computed from statistical characteristics of the slowly varying amplitude envelope of the signal in a narrow pass band centered approximately at the resonance frequency of the sensor.

These statistical flow-indicator quantities are fed to a neural network, which calculates the mass flow rate and other flow parameters of interest. A neural network is used for this purpose because of the inherent ability of a neural network to learn nonlinear correlations that involve abrupt transitions, strongly varying behaviors, or complicated interactions among input variables, even in the absence of a mathematical model of the relationships among the input and output variables. As in the cases of other neural networks, this neural network is programmed by training it with numerous sets of examples of inputs (the statistical flow-indicator quantities) and the corresponding outputs (e.g., the mass flow rate in single-phase flow, the presence or absence of a second phase, and separate mass flow rates of liquid and gas in the case of two-phase flow). The analytical methods are described in U.S. patents 5,600,073, 5,717,691, and 5,741,980.

This work was done by Wayne S. Hill and Bruce N. Barck of Foster-Miller, Inc., for **Stennis Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Foster-Miller, Inc.
350 Second Ave.
Waltham, MA 02451-1196

Refer to SSC-00053, volume and number of this NASA Tech Briefs *issue, and the page number.*

High-Temperature, Fiber-Optic-Readout Pressure Transducers

These transducers could be mounted in harsh environments like those inside turbine engines.

John H. Glenn Research Center, Cleveland, Ohio

Fiber-optic-coupled differential-pressure transducers are being developed for use in hot, harsh environments like those in the cores of aircraft turbine engines. The prior approach to the measurement of pressures in such engines involves the use of pressure transducers coupled to pressure taps via long tubes, which introduce delays and degrade responses to high-frequency pressure variations. In contrast, the fully developed versions of the developmental transducers would be mounted directly in the affected compressor, combustor, and turbine stages; because there would be no long pressure-coupling tubes, these pressure transducers would yield more-accurate readings in more nearly real time. The readings could help to identify conditions that must be corrected in maintenance work and could, potentially, enhance safety in flight by providing indications of impending compressor stall.

The developmental fiber-optic-coupled differential pressure transducers are denoted twin-column transducers (TCTs) for a reason that will immediately become apparent: A transducer of this type includes two tubes (T1 and T2), nominally of identical length and width. The tubes are sealed at their tips and are connected at their bases to sources of the differential pressure to be measured (see figure). Upon pressurization, each tube becomes slightly elongated — by an amount proportional to the difference between its interior pressure and the ambient pressure. Similarly, if a tube is partly or wholly evacuated, it is proportionately shortened. Thus, the differential elongation of the two tubes is proportional to the differential pressure between their interiors. The twin-column design automatically compensates for temperature; that is, any change in ambient temperature affects both tubes nearly equally and thus does not appreciably alter the differential elongation.

The tips of the tubes are capped with assemblies for input and output coupling of light via optical fibers, which are arranged for measuring the differential elongation of the tubes. Input light from a light-emitting diode (LED), provided via a source optical fiber, is aimed from the assembly on T1, across the gap to two receiver optical fibers in the assembly on T2. The positions of the fibers are adjusted so that (1) when the differential elongation of both tubes is zero (corresponding to zero differential pressure), equal amounts of light are coupled into both receiver fibers; (2) any nonzero differ-

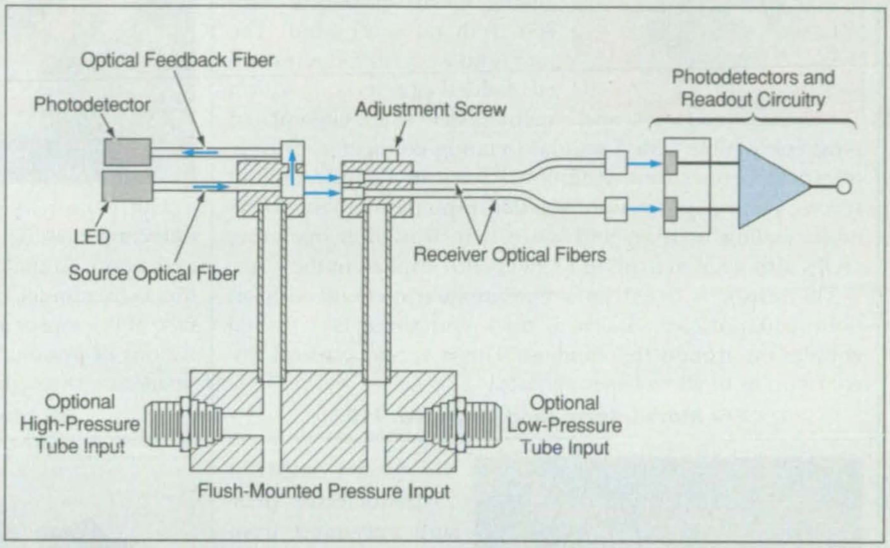
ential elongation of the tubes gives rise to a proportional imbalance between the amounts of light coupled into the receiver fibers; and (3) the sum of amounts of light coupled into both receiver fibers remains constant as the differential elongation changes. As a result, the ratio between the difference and the sum of the receiver-fiber outputs is proportional to the differential pressure.

The LED and the photodetectors and electronic circuitry used to process the output light from the receiver fibers are located safely away from the hostile environment of the TCT. An additional optical fiber can be installed on the T1 side to provide feedback for regulating the intensity of light emitted by the LED; such feedback regulation renders the final differential-pressure reading relatively insensitive to fluctuations of temperature and voltage in the electronic circuitry.

The key components that are expected to make high-temperature TCTs possible are low-loss optical fibers capable of transmitting light between hot engine locations and cooler remote locations where electronic circuitry can be operated in safety. Sapphire optical fibers several meters long, with losses of less than 0.2 dB/km, have been fabricated experimentally. A practical design might provide for short lengths of high-quality sapphire fibers from the point of measurement, coupled to less-expensive commercial sapphire fibers of lower optical quality, and finally to low-loss, low-temperature optical fibers to cost-effectively bring signals out through zones of progressively decreasing ambient temperature.

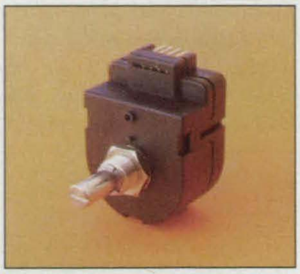
This work was done by Charles A. Liucci of LEL Corp. for **Glenn Research Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16889.



A **Twin-Column Transducer** is a differential-pressure transducer that inherently has a high degree of temperature compensation. Differential pressure in the tubes is determined from fiber-optic measurement of differential elongation of the tubes.

Special Coverage: Sensors



Spectrol Electronics Corp., Ontario, CA, has introduced the Model 601-1045 **industrial position sensor** that provides an analog electrical output over 360° with no dead band. The unit is housed within an insulated molded plastic body with a stainless-steel shaft. Gold-plated pins, compatible with a standard mating connector, provide electrical connections. Additional features include built-in reverse polarity protection, angular response of 50 microseconds, sealing to IP54, and more than 5 million operating cycles with a radial load up to 200 grams applied to the shaft.

The sensor is based on a potentiometric circuit with an unbroken polymer resistance track and three taps placed equidistant around the element. There are no physical discontinuities to affect wiper contact.

For More Information Circle No. 710

SIE Sensors, Toledo, OH, offers the SK1-25-50/10-X-b-X **capacitive proximity sensor** with an adjustable sensing range from 2-25 mm. The sensor is a self-contained unit, operating at 10-35 VDC. It has a switchable output from PNP/NPN, Normally Open/Normally Closed, and an LED indicator visible from 180°. The disc sensor can be flush-mounted and is IP67 rated.

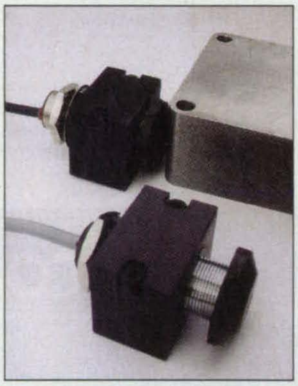
The sensor is designed for limited-space applications, detecting materials such as plastic, glass, metals, ceramics, and wood. Available wiring options are with an M8 or M12 quick-disconnect or the standard 2-meter cable. The active face of the sensor allows for proximity and level sensing applications of powder, granular materials, high-low liquid levels, or sensing through sight-glass windows.

For More Information Circle No. 711

The Model 522M17/19 piezoelectric **pressure transducer** from Endevco Corp., San Juan Capistrano, CA, senses dynamic pressure fluctuations up to 500 psi in the presence of high static pressure and temperature. It utilizes ferro-piezoelectric ceramics in the charge mode. The transducer features Inconel construction and a metal-sheathed integral cable.

Transducer output is accommodated by a 10-foot tri-axial hardline cable with a 10-32 coaxial receptacle on the M17, and a 5-44 coaxial receptacle on the M19. The transducer requires no external power and can operate continuously at 538°C. It also can operate intermittently in temperatures to 649°C.

For More Information Circle No. 712



SoftNoze USA, Frankfort, NY, has introduced Blockstyle **cushioned sensor mounts** that combine spring-loaded housing with an anodized aluminum block mount for 8, 12, 18, and 30 mm sensors. The sensor mounts are designed to protect sensors from abrasion and accidental impact.

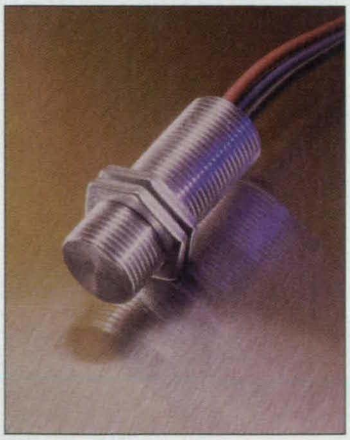
Spring-loaded sensor mounts enable tubular proximity sensors to retract upon impact and then return to their normal sensing position when the target passes. Each spring-loaded mount includes a plastic EndNoze cap to prevent abrasion. The caps are beveled to allow activation of a cushioned sensor mount from a laterally moving target.

For More Information Circle No. 713

The E2EM long-distance **proximity sensor** from Omron Electronics, Schaumburg, IL, features an LED indicator mounted on the back of the sensor for operator indicator viewing. Also featured is a clear plastic strain relief that provides protection against cable pulling and flexing. The DC 2 Wire version senses up to 30 mm.

The sensor has wrench flats to allow for tightening. Increased barrel thickness allows for greater torque of mounting hardware, preventing loosening from vibration. Applications include machine tool, conveyor systems, material handling, and packaging.

For More Information Circle No. 714



Power Components of Midwest, Mishawaka, IN, offers an omni-directional, zero-speed **digital sensor** that operates with an air gap up to 5 mm. The sensor is a Hall effect device that senses the rotation of steel gear teeth or notches without the need for external magnets. It is hermetically sealed, fully encapsulated, and able to withstand harsh environments. The sensor has available operating temperatures of -40°C to 150°C. Custom-designed packages or the standard package are available in either a 2-wire (#GS-40) or 3-wire (#GS-60) configuration.

For More Information Circle No. 715

The last time a traditional spacecraft supplier built a new manufacturing factory

We concede the nostalgic appeal. But chances are, Dad's retired the car for a more efficient model while some four decades later, traditional space contractors are still producing satellites from their old-style manufacturing plants. At Spectrum Astro, we're putting our customers in the fast lane with a new manufacturing, integration and test facility designed for unparalleled efficiency. By the end of Phase One in 2001, we'll occupy over 274,000 square feet of floor space with a growing team of engineers dedicated to building the next generation of spacecraft faster and more reliable than ever. And with the capacity to build and test up to 27 satellites simultaneously, we're incorporating more innovative tools and practices to maximize satellite producibility and rapid production rates. Ideal for programs like SBIRS Low requiring the accelerated delivery of multiple satellites at lower cost, or for smaller, single satellite programs with high performance goals. Because today, success means delivering better satellite solutions on time and on budget. Which is to say, the rules of the road have changed.

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Electronic Components and Systems

Airborne Multichannel Swept-Tuned Spectrum Analyzer

Dynamic data are transmitted in real time despite limited telemetry bandwidth.

Dryden Flight Research Center, Edwards, California

Figure 1. The **Pegasus® Air-Launched Space Booster Rocket** is shown here at ignition of its engine after being dropped from a carrier aircraft. (NASA photo by Jim Ross.)

Two airborne spectrum analyzers were developed for acquiring dynamic data, characterized by frequencies up to 25 kHz, from a hypersonic-crossflow-transition experiment aboard the air-launched Pegasus® space booster rocket (see Figure 1). Real-time transmission of time histories of the dynamic data via a pulse-code modulation (PCM) telemetry encoder would have required sample rates of at least 50,000 s^{-1}. The telemetry bandwidth necessary to support rates as high as this was not available; however, conversion of the data to the frequency domain aboard the rocket would make it possible to trade frequency resolution for a reduction in telemetry bandwidth. The two airborne spectrum analyzers implement this type of conversion. One spectrum analyzer is based on a swept-tuned receiver; the other is based on digital signal processing technology. The remainder of this article describes the swept-tuned spectrum analyzer.

Spectrum analyzers are typically used for radio-frequency measurements. Because the measurement bandwidth in the hypersonic-crossflow-transition experiment extended only slightly beyond the audio range, commercially available analog function modules (rather than radio-frequency components) were used in constructing the swept-tuned spectrum analyzer. They included an analog multiplier instead of a mixer, a root-mean-square-to-direct-current (rms-to-dc) converter as an envelope detector, and a digital sine-wave generator combined with a voltage-to-frequency converter for a local oscillator (LO). In lieu of a conventional display, the amplitude and frequency outputs of the analyzer were sampled by a PCM encoder. Then the display was obtained on the ground (where the calibrations were applied) by plotting the amplitude readings against the frequency readings.

The lower part of Figure 2 shows two vibration spectra obtained during one flight. The dashed line represents the vibration level while the rocket was held by the launching aircraft prior to launch; the solid line represents the vibration level at a high angle of attack after ignition of the rocket motor.

Calibration of the spectrum analyzer was done by Philip J. Hamory of **Dryden Flight Research Center.** *Design was done by John K. Diamond of Langley Research Center. Analysis of data was done by Arild Bertelrud of Analytical Services and Materials, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
DRC-00-12

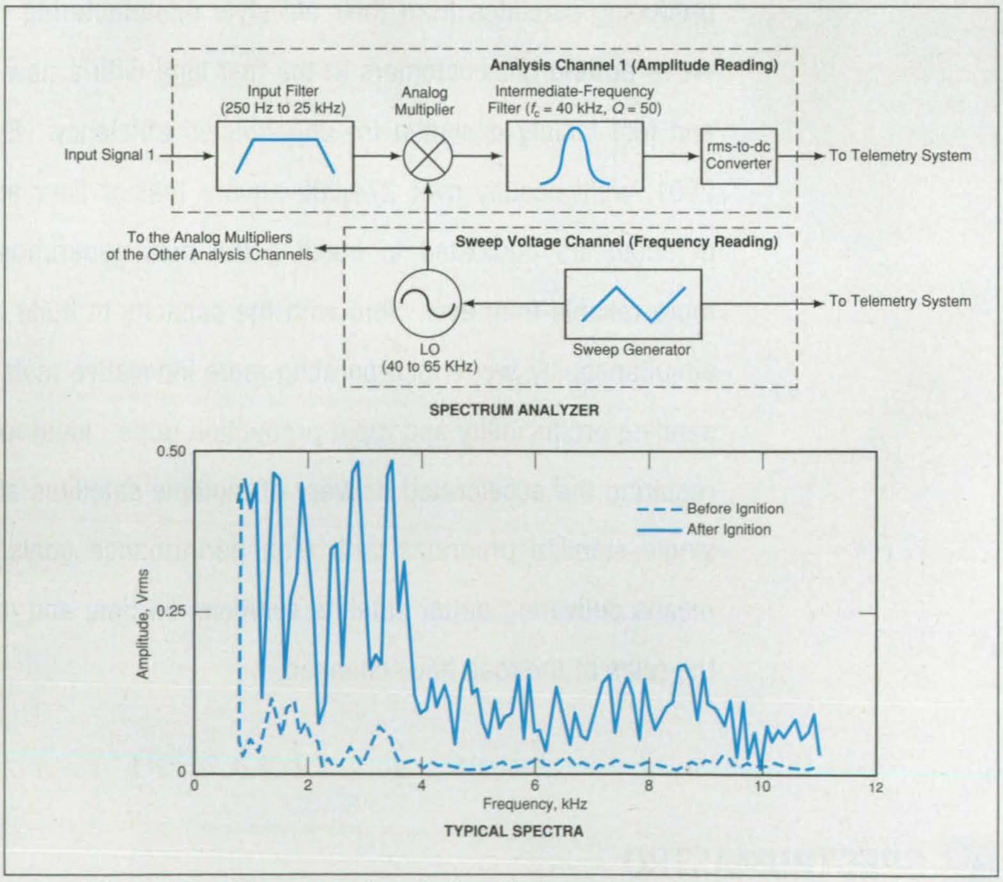

Figure 2. The **Swept-Tuned Spectrum Analyzer** developed for Pegasus® experiments contains four signal-processing channels, of which the major functional blocks are depicted here. The plots at the bottom are spectra obtained with the help of the swept-tuned spectrum analyzer.

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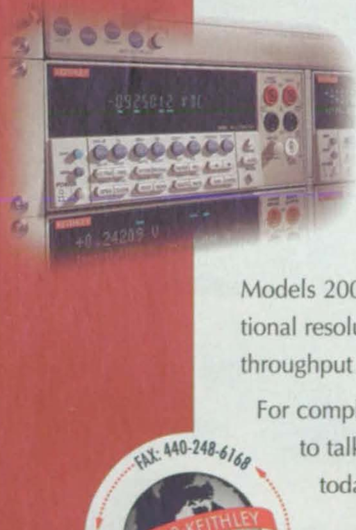

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• Ohms	100μΩ – 120MΩ	1μΩ – 120MΩ	1μΩ – 1GΩ	100nΩ – 1GΩ
• DC amps	10nA – 3A	1nA – 3A	10pA – 2.1A	10pA – 2.1A
• AC amps	1μA – 3A	1μA – 3A	100pA – 2.1A	100pA – 2.1A

For More Information Circle No. 544

Improved Eye-Tracking Apparatus

Spurious effects of ambient infrared light have been reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

A previously developed apparatus that tracks the orientation of the human eye has been modified to make it less susceptible to error induced by ambient infrared light. The apparatus is a commercial product intended primarily for use as a computer-control interface for a person who is physically unable to use a keyboard.

The unmodified apparatus includes a near-infrared source that illuminates the eye, plus an infrared video camera that monitors the eye. The source and camera optics are combined so that the infrared illumination strikes the eye along the optical axis of the video camera. The total video image comprises a bright image of the pupil plus a very bright specular reflection from the cornea. The total video image is processed to obtain a vector between the center of the pupil and the corneal reflection. This vector constitutes the desired information on the orientation of the eye (the gaze direction).

The unmodified apparatus incorporates several features to minimize the effect of ambient infrared light: The infrared source is a narrow-band light-emitting diode (LED) that operates at high power. A band-pass optical filter is placed in front of the video camera to block as much ambient infrared light as possible while passing the infrared light from the LED. Despite these features, infrared light from the Sun, incandescent lamps, and other sources can decrease the signal-to-noise ratio of the pupil and corneal-reflection images so much as to introduce errors or even cause the apparatus to lose track of the eye. Thus, to ensure reliable operation, the unmodified apparatus must be used indoors, with shades drawn to reduce sunlight, and with no incandescent lamps lit (fluorescent lamps are acceptable).

Accordingly, modifications were made to increase the signal-to-noise ratio in the presence of ambient infrared light. The modifications were (1) replacement of the LED by a different LED of narrower spectral width and of greater power within eye-safe limits and (2) replacement of the band-pass optical filter with another one that is better matched to the new infrared LED. The new infrared LED operates at a power of 32 mW in a wavelength band 40 nm wide at a nominal wavelength of 880 nm. The new optical band-pass filter has a wavelength pass band only 10 nm wide. Although the filter wavelength pass band is only 1/4 as wide as the emission wavelength band of the LED, computer simulations nevertheless showed that a greater signal-to-noise ratio could be achieved with this filter than with a filter of 40-nm bandwidth.

The modifications have increased the signal-to-noise ratio by a factor >20. The modified apparatus operates under ordinary indoor lighting, without need to turn off incandescent lamps.

This work was done by John Morookian and James Lambert of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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Test and Measurement

Algorithm for Calibrating an Imaging Interferometer

Conventional "flat-field" calibration is obviated and systematic noise is reduced.

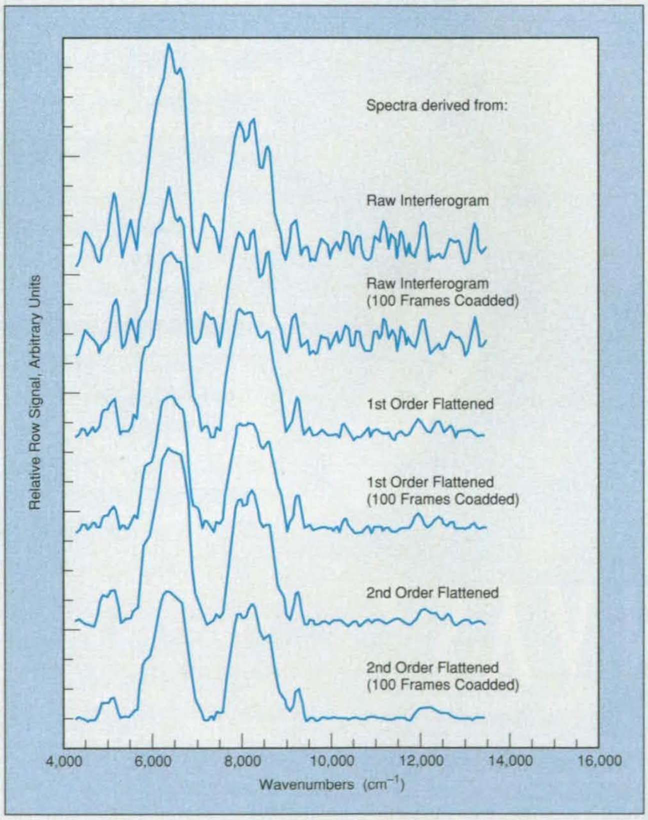
Ames Research Center, Moffett Field, California

An algorithm has been devised to greatly simplify and improve the calibration and the reduction of systematic noise of an imaging interferometer or other similar interferometric instrument. Prior to the advent of this algorithm, such calibration was achieved by means of a conventional "flat-field" correction method that requires uniform illumination of all pixels in the image detector of the instrument. To achieve uniform illumination, it is often necessary to disassemble the instrument to separate the image detector from the instrument optics, taking care to keep all optical and electronic components clean and to restore the original optical alignment upon reassembly.

This algorithm makes it unnecessary to illuminate the detector uniformly or to perform difficult and time-consuming laboratory calibration, disassembly, and reassembly procedures. Calibration information can be extracted from ordinary images — even from highly variable scenes. With this algorithm, calibration can be performed with much more flexibility — in the laboratory or in the field. Moreover, the algorithm makes it possible to calibrate the instrument in nearly real time — immediately before or after acquisition of interferometric images — so that one can have some assurance that there has not been enough time for vibrations and other environmental factors to affect the calibration significantly.

Imaging interferometers for which this algorithm was designed acquire a spectral image one spatial line at a time on an image detector that contains a two-dimensional pixel array. In contrast to a conventional scanning interferometer, the optics in this imaging interferometer are fixed. The array is illuminated by two beams of light that interfere coherently, giving rise to an interferogram. The interferograms are recorded, then Fourier-transformed to obtain spectra.

The optical configuration of the instrument is such that each pixel along one dimension represents an increment of position along the spatial line, while each pixel along the perpendicular dimension represents an increment of the path-difference between the two interfering beams at that position. The data product of the interferometer, obtained by putting together the spatial and Fourier-transform spectral information from all spatial lines across a scene, is an image "cube" that comprises a two-dimensional spatial image with an inverse Fourier transform of a spectrum for each spatial pixel.

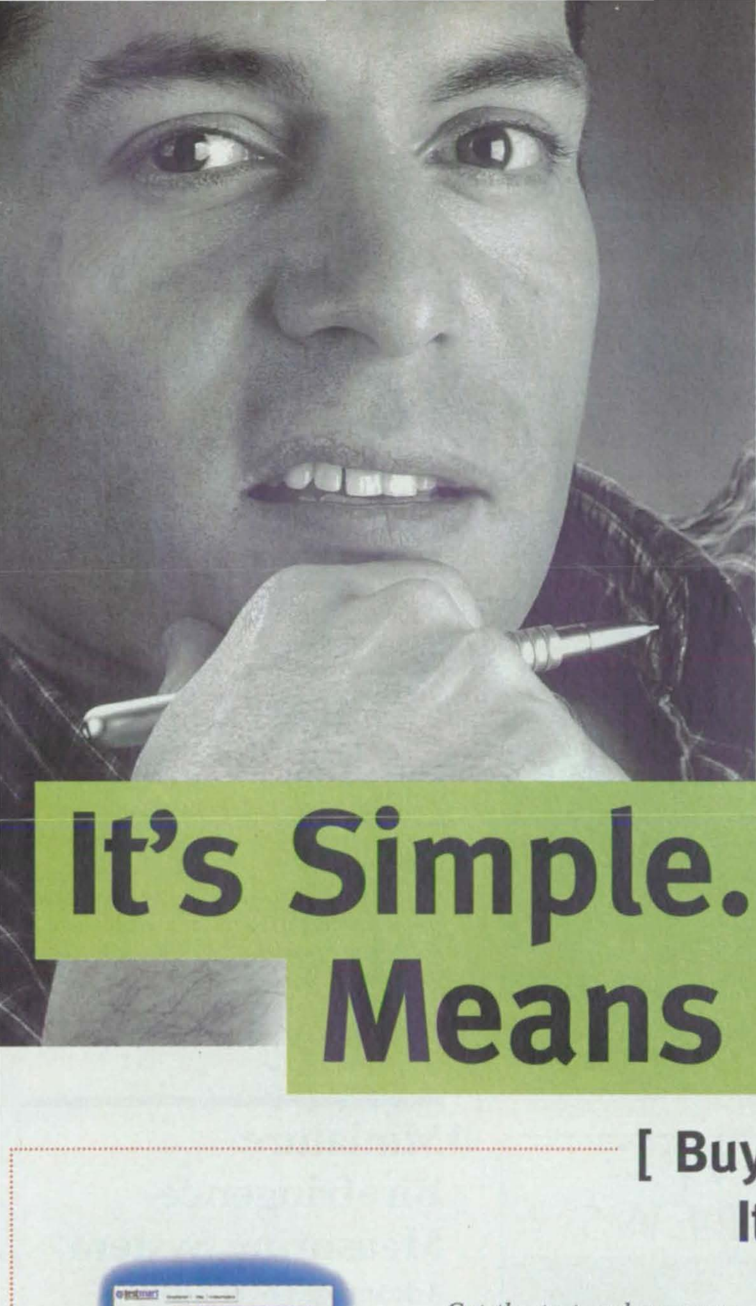


The Results After Various Stages of Processing are shown for a particular interferogram row of a detector array. The plot shows corresponding spectra of the interferograms after Fourier transformation.

The present calibration algorithm exploits the special physical and mathematical characteristics of the two-beam interference phenomenon (i.e., constraints and symmetry properties), as rendered by the optics of the instrument onto the detector plane. The spatial and interferogram coordinates at the detector plane are orthogonal and thus separable. Thus in principle, a single frame observation that is uniform along the spatial coordinate (or an average of many frames that approaches such uniformity) will yield fringes of equal inclination and that are parallel or unvarying along the spatial coordinate. The algorithm transforms real, imperfect fringe patterns so that they can be represented as fringes of equal inclination, enabling a very effective extraction of systematic noise for subsequent use in treating data cubes on a frame-by-frame basis.

The algorithm prescribes a series of reversible transformations to the two-dimensional Fourier domain of the pixel-array space. An important part of the algorithm is a row-wise-phase-alignment subalgorithm that is analogous to the formalism used to process asymmetrical interferograms produced by scanning Fourier spectrometers. Phase alignment eliminates the effects of variation in interference-fringe path-difference scales over rows of the detector plane. The resulting signal in Fourier space then represents the spectrum of the row-wise coherently coadded interferograms of an entire frame, is highly localized, and is optimally isolated from noise and systematic errors. The signal is filtered out, then an inverse composite transformation is performed to obtain a pixel-variation frame that is used to treat the image data.

The algorithm does not depend on such instrument parameters as the spatial and spectral ranges and resolutions. Additionally, the algorithm treats bad detector pixels in a self-consistent manner, and aberrations caused by imperfections in the detector and associated optics are ac-



commodated. Image data treated by the algorithm approach the fundamental limit (defined by photon shot noise or random detector noise) of the signal-to-noise capability of the instrument. The benefits obtained from applying the algorithm to typical radiative spectra of the atmosphere are designated as "2nd order flattened" in the figure.

The algorithm has been implemented in prototype software that includes parts in Interactive Data Language (IDL) together with a comprehensive set of routines for processing imaging-interferometer-type data. It should be possible to make a commercially viable software product by translating the IDL code into an efficient computing language and integrating it with a comprehensive data-processing-and-visualization program that includes a user interface.

This work was done by Philip D. Hammer of **Ames Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Test and Measurement category.*

This invention has been patented by NASA (U.S. Patent No. 5,675,513). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14054.

Miniature Birefringence-Measuring System

Advantages over older systems include compactness, light weight, low power consumption, and greater sensitivity.

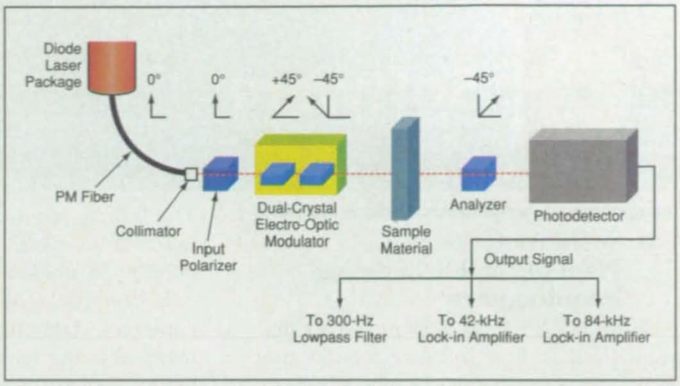
John H. Glenn Research Center, Cleveland, Ohio

A miniature birefringence-measuring system has been developed for use in investigating extensional flows of non-Newtonian polymers in microgravity. The system could also be used on Earth to perform general optical-retardation and dichroism measurements, to measure stresses with high sensitivity, to characterize polymers, and to measure orientation angles of molecular chains. The system includes a dual-crystal transverse electro-optical phase modulator that makes it possible to measure small (of the order of 10^{-9}) changes in the birefringence of a material under test as the material is subjected to extensional deformation or shear stress.

Moreover, because the modulation frequency can be > 100 MHz, it may be possible to use the system to study chaotic flow birefringence.

Previously developed phase-modulation birefringence-measuring systems have traditionally been built around single-crystal photoelastic modulators (PEMs). One representative fused-silica PEM assembly for visible light weighs 9.1 kg and has a 27-mm useful aperture. A typical previously developed system can occupy 2 m of lineal space. Given these typical weight and size parameters, previously developed systems are too heavy and large for many applications. In contrast, the present miniature birefringence-measuring system weighs only about 2.5 kg and occupies only 28 cm of lineal space. In addition to smaller size and weight, the advantages of this system over previously developed birefringence-measuring systems include lower power consumption, greater robustness, shorter warmup time, and greater accuracy and sensitivity in the birefringence measurement.

The modulator in this system is a commercially available one that contains two $LiNbO_3$ crystals oriented with their principal axes orthogonal to each other and at ±45° with respect to the polarization of incident laser light. The figure depicts the basic optical configuration. The second crystal is needed to counteract effects of thermal instability because the static birefringence of $LiNbO_3$ is highly temperature-dependent. In addition, when the modulation voltage applied to the second crystal is 180° out of phase with that applied to the first crystal, the effective modulation depth is doubled.



This **Birefringence-Measuring System** includes a dual-crystal electro-optical modulator, which is depicted here schematically in its geometric relation to polarization and to the other optical components.

The system has been calibrated by incrementing the modulator driver voltage and mapping the appropriate Bessel functions. Calibration data were taken at 500 points, and the experimentally generated calibration curves were found to agree with the expected curves at every data point with a worst correlation error of less than 0.5 percent. This is an order of magnitude better than the accepted calibration standard, for which the worst correlation error ranges from 2 to 5 percent. This system has also been tested against a PEM-based birefringence-measuring system, with favorable results.

This work was done by Jeffrey R. Mackey of Analex Corp. for **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Test and Measurement category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16705.

Software Collects Planning and Scheduling Requirements

Interim User's Requirements Collection (IURC) is a software system that generates an interactive graphical user interface that enables users of the International Space Station (ISS) to specify their payload-planning and -scheduling requirements via the World Wide Web (WWW). IURC includes (1) a Java applet that is dynamically distributed via the WWW and (2) four application programs that run on a dedicated host computer with a web server at Marshall Space Flight Center (MSFC).

The need for a system like IURC to collect ISS payload planning and scheduling requirements arises from several causes. The requirements are complex, lengthy, and diverse. The scarcity of Space Station resources causes significant competition for resources among experiments. In order to be able to perform its scheduling task, the Payload Operations Integration Center at MSFC needs a concise and comprehensive description of payload requirements (to ensure a valid schedule) and a good description of the payload flexibilities (to provide for effective utilization of available resources). In addition, the continuous operation of the ISS, the wide geographic dispersion of ISS users, and budgetary pressure to employ fewer operational personnel have made it necessary to seek an inexpensive solution in the form of software.

IURC incorporates three distinct innovations that synergistically ensure effectiveness in the collection of planning and scheduling requirements, with the needed fidelity and convenience, and at a cost less than the costs of other methods. These innovations are the following:

- The major innovation is a provision for graphical specification of requirements. IURC does more than merely use graphics to depict or interpret data entered via tables or forms; the graphical user interface is the data-entry mechanism.
- IURC provides "just-in-time" configuration control that is not visible to users. Configuration control begins when a user says that a set of data is ready to go; at this point, IURC makes a copy of the set of data. Users who enter data never see any effect of configuration control. Their data are not "locked," so that users never need to request that the data be "unlocked." Users are free to edit their data at will. However, the copies of data that users have designated as being ready to go and that are being used to produce ISS time lines are under full configuration control.
- The WWW implementation enables a user to interact with the system via a personal computer from any location. All data are kept on the web server at MSFC; except for entering data as described above, users never move, send, or track their data. In addition, by utilizing the combination of (1) a universally installed web browser and (2) the dynamically downloaded JAVA applet, IURC eliminates the need for users to install any software, yet is globally available to users.

This work was done by John Jaap and Elizabeth Davis of **Marshall Space Flight Center**. *For further information, please contact the MSFC Software Release Authority at (256) 544-7175.*
MFS-31416

Software for Ground Processing of Data From Landsat 7

Three computer programs have been developed for ground processing of Enhanced Thematic Mapper Plus (ETM+) data from Landsat 7. The three programs and their functions are the following:

- The Landsat Processing System (LPS) program processes the Landsat 7 ETM+ data received by the Landsat ground station into an archival data product.
- The Image Assessment System (IAS) program assess the quality of ETM+ data and performs calibration of the ETM+.
- The Level 1 Product Generation System (LPGS) program generates level-1 ETM+ digital image data products (this means that LPGS performs radiometric and geometric corrections of ETM+ digital image data).

This software differs from the software used to process data from older satellites of the Landsat series. The content and format of the Landsat 7 wide-band (X-band) data stream are unique to the Landsat 7 system. While the data acquired by the Thematic Mapper sensors aboard the Landsat 4 and Landsat 5 satellites are similar to the ETM+ data, the ETM+ data stream received at the ground station is significantly different, such that the ground data-processing software developed for the older Landsat satellites cannot be used for ground processing of Landsat 7 data. Hence, it was necessary to develop the present three programs to handle the Landsat 7 ETM+ data.

A major difference between Landsat 7 and the older Landsat satellites is that Landsat 7 incorporates new radiometric calibration sources. The IAS program, in particular, implements new procedures for exploiting ETM+ observations of these sources for radiometric calibration.

The IAS source code is original. Large portions of the IAS source code were reused in developing the LPGS program.

The IAS program includes commercial-off-the-shelf software [Oracle for a data base and IDL for some digital image analyses], but these commercial programs are not embedded in the version of the IAS source code that the authors intend to distribute.

The software consists of lines of source code written principally in the C programming language and accompanied by descriptive documentation. The software is designed exclusively to run on the computer systems of the U.S. Landsat 7 ground data processing system, developed under management of the NASA Goddard Space Flight Center and delivered to the Earth Resources Observation System (EROS) Data Center of the U. S. Geological Survey for use during operations in orbit.

The Landsat 7 satellite is expected to transmit ETM+ data to a number (circa 10) of ground stations distributed around the globe. The stations are expected to be operated by international cooperators (foreign governments or government consortia) that will pay license fees to the U.S. Geological Survey. The LPS, IAS, and LPGS source code will be of greatest interest to those involved in the development of the ground data processing systems for international cooperators. Other organizations interested in creating data products derived from ETM+ data for their customers may also be interested in this software.

This work was done by Robert J. Menrad of **Goddard Space Flight Center**, *Mina Samii of Computer Sciences Corp., and R. J. Thompson of the U. S. Geological Survey.*
GSC-14244

Extended Shelf Life for PMR Polyimide Resins and Prepregs

Secondary alcohols are used in place of primary alcohols.

John H. Glenn Research Center, Cleveland, Ohio

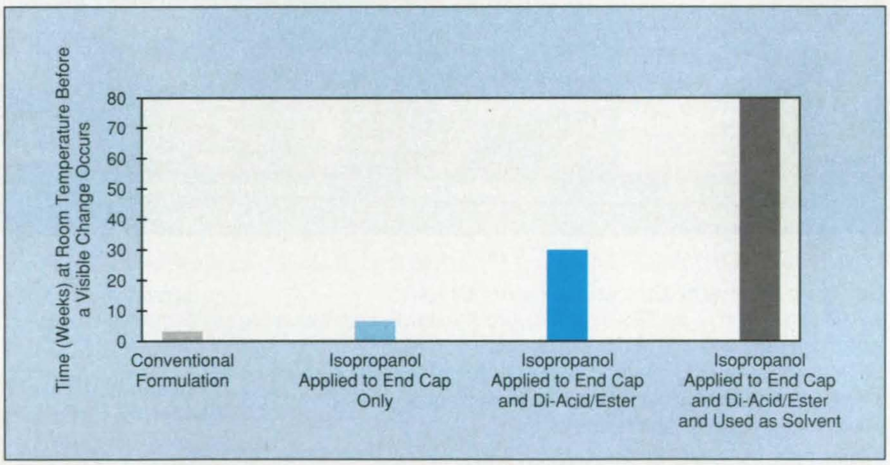
An improved class of formulations for PMR polyimide resins retards the imidization that undesirably occurs during handling and storage. While imidization is desired at the final (deliberate polymerization) stage of production of a polyimide, imidization results in premature aging when it occurs during earlier stages of synthesis, shipping, prepregging, and fabrication layup. By retarding imidization at storage and handling temperatures, the improved class of formulations increases both shelf life and the upper limit of allowable temperature for handling and storage prior to final polymerization.

The improved class of formulations is best explained with reference to the origin of the PMR concept: U.S. Patent 3,745,149, issued on July 10, 1973, disclosed that polyimides can be synthesized from mixtures of monomeric reactants that have been prepared by using lower (primary) alcohols (usually, ethanol or methanol) to esterify anhydride end caps and aromatic dianhydrides. The primary alcohols are also used as solvents for the reactants. A solution that incorporates such reactants plus an aromatic diamine in the mole ratio of [N diester diacid: N+1 diamine: 2 ester acid end cap] constitutes a monomeric mix which, at high temperature, polymerizes ("cures"), becoming a polyimide; hence, the evolution of the term "polymerization of monomeric reactants," now known better by its abbreviation, "PMR." Numerous variations of the basic PMR concept have been published since the original patent was issued, but, until now, none of these variations has departed from the use of primary alcohols to prepare methyl or ethyl ester acids.

The major disadvantages of conventional commercial PMR formulation and processing are limited shelf life at room temperature, short working life, and high sensitivity to temperature excursions above room temperature. These disadvantages are associated with premature imidization during all phases of PMR usage (synthesis, manufacturing, shipping, handling, storage, and fabrication). For example, typical commercial PMR-15 polyimide prepregs are out of manufacturing specification after a shelf life of only one to three weeks at room temperature. In many cases, the shelf life is even shorter for other PMR formulations, e.g., PMR-II-50. While PMR shelf life and working time can be extended by refrigeration and ensured by careful monitoring of temperature histories, this practice adds to the costs of PMR products.

The improved class of formulations involves the use of secondary alcohols (usually, isopropanol) instead of primary alcohols for esterification of the anhydride end caps and dianhydride monomers and as solvents for the resulting isopropyl ester acids. In comparison with PMR resins made conventionally by use of primary alcohols, PMR resins made by use of isopropanol are less reactive at comparable storage or handling temperature, without changing typical imidization or curing temperatures. For example, PMR-15 resin made with isopropanol may be stored or handled at temperatures up to 50 °C higher than PMR-15 resin made with a primary alcohol (methanol) in order to produce comparable amounts of imide-aging products in both resins after equal handling and storage times.

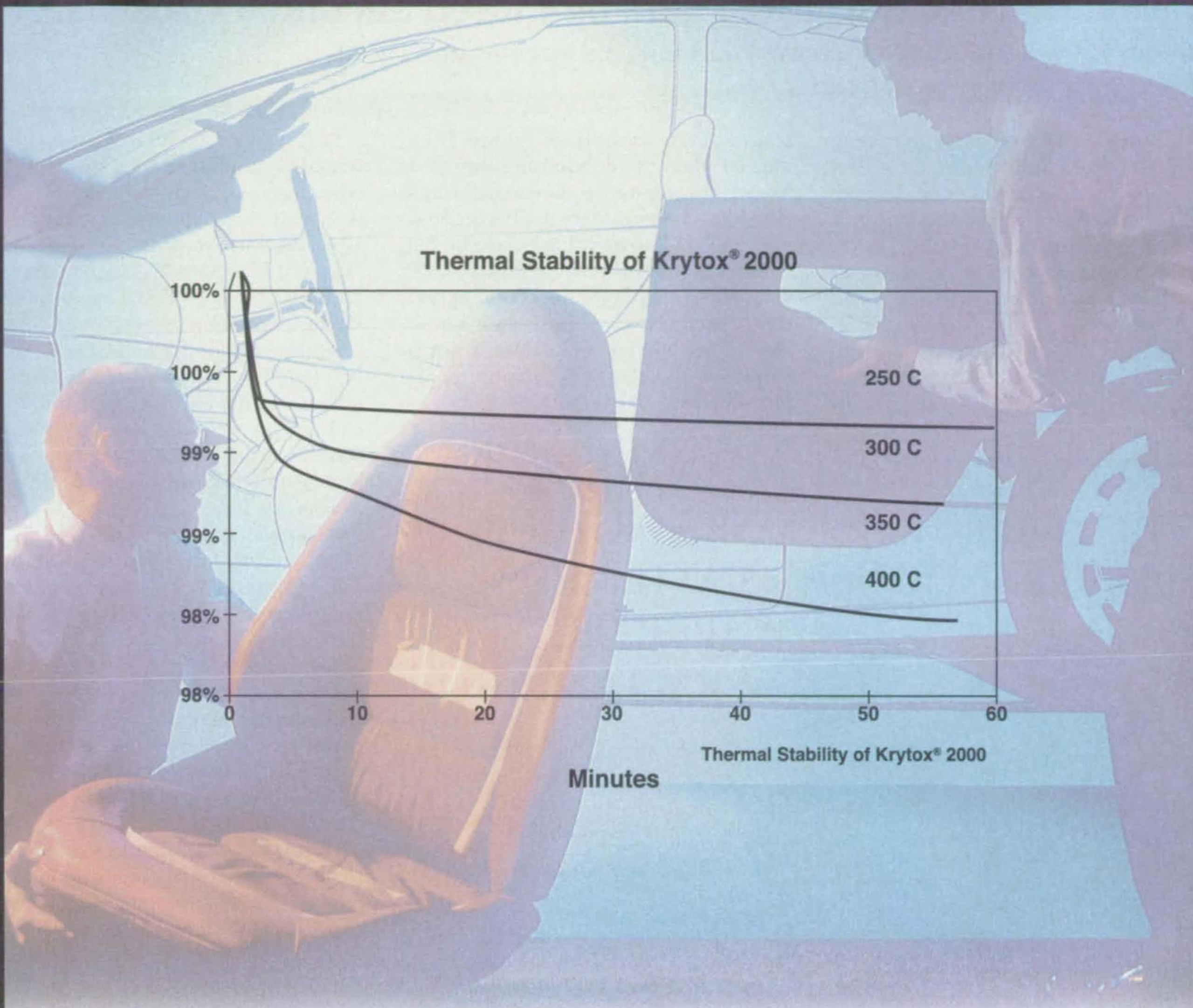
This improvement affords a wide margin against mishandling of PMR solution, reducing or, in some cases, eliminating the need for refrigeration and monitoring of temperature histories. The results include not only increased shelf life (see figure) but also decreased costs of shipping and handling, more consistent processability, reduced variability among batches, improved hot-melt prepreg manufacturing, and reduced scrap rates. The improved formulations are also safer because in comparison with primary alcohols, isopropanol is less toxic and less flammable. Also, the longer retention time of isopropanol compared to methanol or ethanol during composite processing may be beneficial to some processing techniques, e.g., solvent-assisted resin transfer molding (SARTM) techniques.



Shelf Lives of Four PMR-15 Solutions were measured. The solutions were products of four different formulations, ranging from the conventional formulation (primary alcohols used as esterification reagents and solvents) through partly conventional and partly improved formulation (isopropanol substituted for primary alcohols in some aspects) to totally improved formulation (isopropanol used exclusively as esterification reagent and solvent).

This work was done by William B. Alston of the Army Research Laboratory; Daniel A. Scheiman of Dynacs Engineering, Inc.; and Gloria S. Sivko of **Glenn Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16691.



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Plasma CVD of Boron Carbide by Pulsed Secondary Discharge

Rates of deposition can be increased and internal stresses decreased.

John H. Glenn Research Center, Cleveland, Ohio

An improved method of plasma chemical-vapor deposition (CVD) of a thin film of boron carbide has been devised. Boron carbide is useful because it is hard, is electrically insulating, withstands high temperature, and resists chemical attack. Plasma CVD of boron carbide involves the thermal dissociation of feed gases BCl_3, CH_4, and H_2. Prior to the development of the improved method, it had been found that in plasma CVD, the rate of growth is enhanced when the deposition substrate is biased with a positive dc voltage, which gives rise to a secondary discharge. However, the applied dc voltage must be limited (1) so that the current drawn by the secondary discharge does not exceed the capacity of the bias power supply, and/or (2) the current drawn is not so large as to adversely affect the boron carbide deposit.

In the improved method, the bias potential is pulsed instead of steady. Taking advantage of the ability of a pulse circuit to sustain high voltage and the associated high current for a short time, pulses of bias potential higher than the limiting dc bias potential can be applied to the deposition substrate. The pulse-repetition frequency and duty cycle can be chosen so that for a given high potential, the time-averaged secondary-discharge current does not exceed the capability of the power supply or is not so high as to harm the deposit. For a given pulse-repetition frequency, one can trade applied potential versus duty cycle at the limiting time-averaged current; in other words, one can choose a potential as high as desired, as long as one makes the duty cycle short enough.

The beneficial effect of increasing the applied potential is attributed to a consequent increase in electron temperature. The higher the electron temperature, the greater the rate of dissociation of feed-gas molecules by impact of electrons.

During CVD of boron carbide and some other hard materials, part of the momentum of impinging ions becomes converted to internal stresses, which accumulate as the deposits grow. The buildup of internal stresses limits the maximum desirable thickness of a deposit in the sense that if one attempts to make the deposit thicker, the internal stresses are released through the formation of cracks. In the improved method, the peak potential, pulse-repetition frequency, and duty cycle can be regarded as process parameters that can be adjusted to prevent the formation of cracks: The magnitude of the bias defines the momentum and kinetic energy of the impinging ions, whereas the duty cycle and the pulse-repetition frequency define the time during which the deposited material can release some of its internal stresses.

This work was done by Joachim V. R. Heberlein and Olivier B. Postel of the University of Minnesota for **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16716.

Mechanics

Magnetic Couplings for Gas-Driven Catapults

Projectiles would move along the outsides (instead of the insides) of launching tubes.

Marshall Space Flight Center, Alabama

A proposed magnetic-coupling scheme would afford additional degrees of freedom to optimize the designs of gas-driven catapults or launchers. The scheme could be applied to gas guns in diverse applications, including launching spacecraft or aircraft, propelling various objects at high speeds along the ground, and accelerating objects to high speeds for research on hypervelocity impacts.

Heretofore, the usual approach to designing a gas-driven launcher has involved designing a launching tube to accommodate the projectile; the rear end of the projectile would be configured as a piston, and pressurized gas would be introduced into the tube behind the piston to accelerate the projectile to the desired muzzle velocity. If the projectile is a spacecraft, aircraft, or other large object, then this approach entails major disadvantages in that the tube must be made very wide and the amount of pressurized gas that must be supplied is correspondingly large.

The proposed magnetic-coupling scheme would make it possible to launch a projectile by use of one or more launching tube(s) narrower than the projectile. Thus, one could design a launching system that would function with a smaller amount of gas (albeit at a higher pressure needed to generate the required accelerating force over a smaller piston area). By making it possible to use a narrower tube or tubes, the proposed scheme would also make it possible or easier to design a staged compressed-gas system that would utilize compressed gas and compression energy more efficiently.

This work was done by Glen A. Robertson of **Marshall Space Flight Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at (256) 544-5226 or sammy.nabors@msfc.nasa.gov. Refer to MFS-31184.

Differential-Pressure Relief Valve

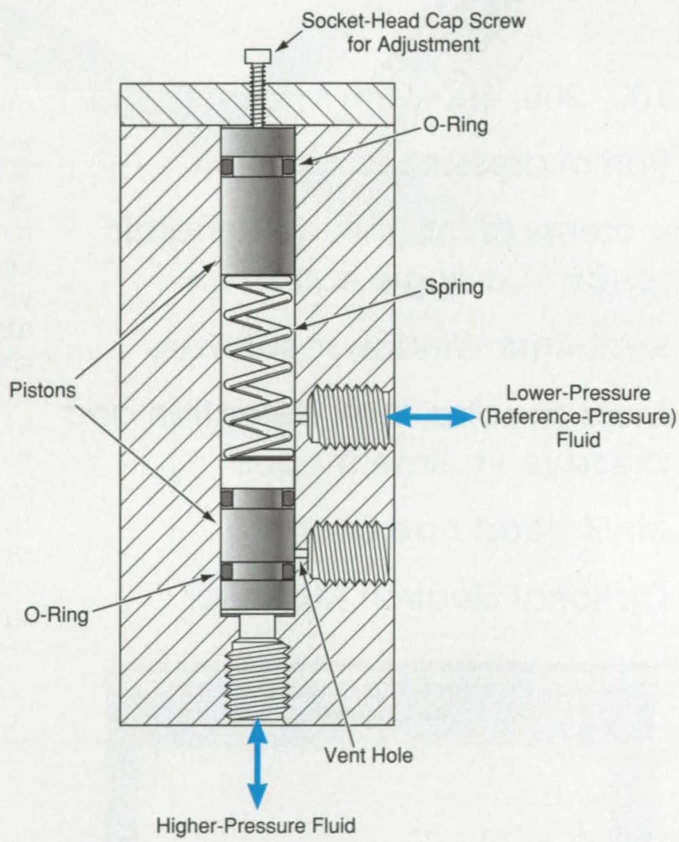
Differential pressure between two fluids can be regulated without mixing them.

Lyndon B. Johnson Space Center, Houston, Texas

A relief valve has been designed to limit the differential pressure between two fluids that are not allowed to be mixed. This valve offers advantages over both simple check valves and simple relief valves. A simple relief valve vents a fluid at the preset absolute relief pressure, but offers no means for limiting the differential pressure between two fluids. A simple check valve can be used to limit the pressure between two fluids, but when the valve opens to relieve differential pressure, one fluid flows into the other one; thus, a simple check valve is not suitable for a system in which the two fluids must not be mixed.

The present valve (see figure) includes two pistons, one of which is spring-loaded and slides in response to the balance between the differential pressure and spring forces. The other piston rests against a hard stop provided by a socket-head cap screw, which is used to adjust the spring load and thus the differential-pressure relief setting. O-ring seals on the pistons prevent mixing and unintended venting of the fluids.

The lower-pressure fluid is deemed to be at the reference pressure and is connected via the uppermost (in the figure) port. The higher-pressure fluid is connected via the lowermost port. When the higher pressure exceeds the reference pressure by the preset amount, the piston moves upward, uncovering a vent hole and thus allowing excess higher-pressure fluid to escape without mixing with the lower-pressure fluid.



This **Differential-Pressure Relief Valve** vents the fluid that enters the lowermost port when its pressure exceeds the reference pressure by a preset amount. There is no mixing of the higher-pressure and lower-pressure fluids.

This work was done by Joseph Robert Trombley of **Johnson Space Center** *and James Dwight Baker and James Everett Bryan of McDonnell Douglas Corp. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
MSC-22607

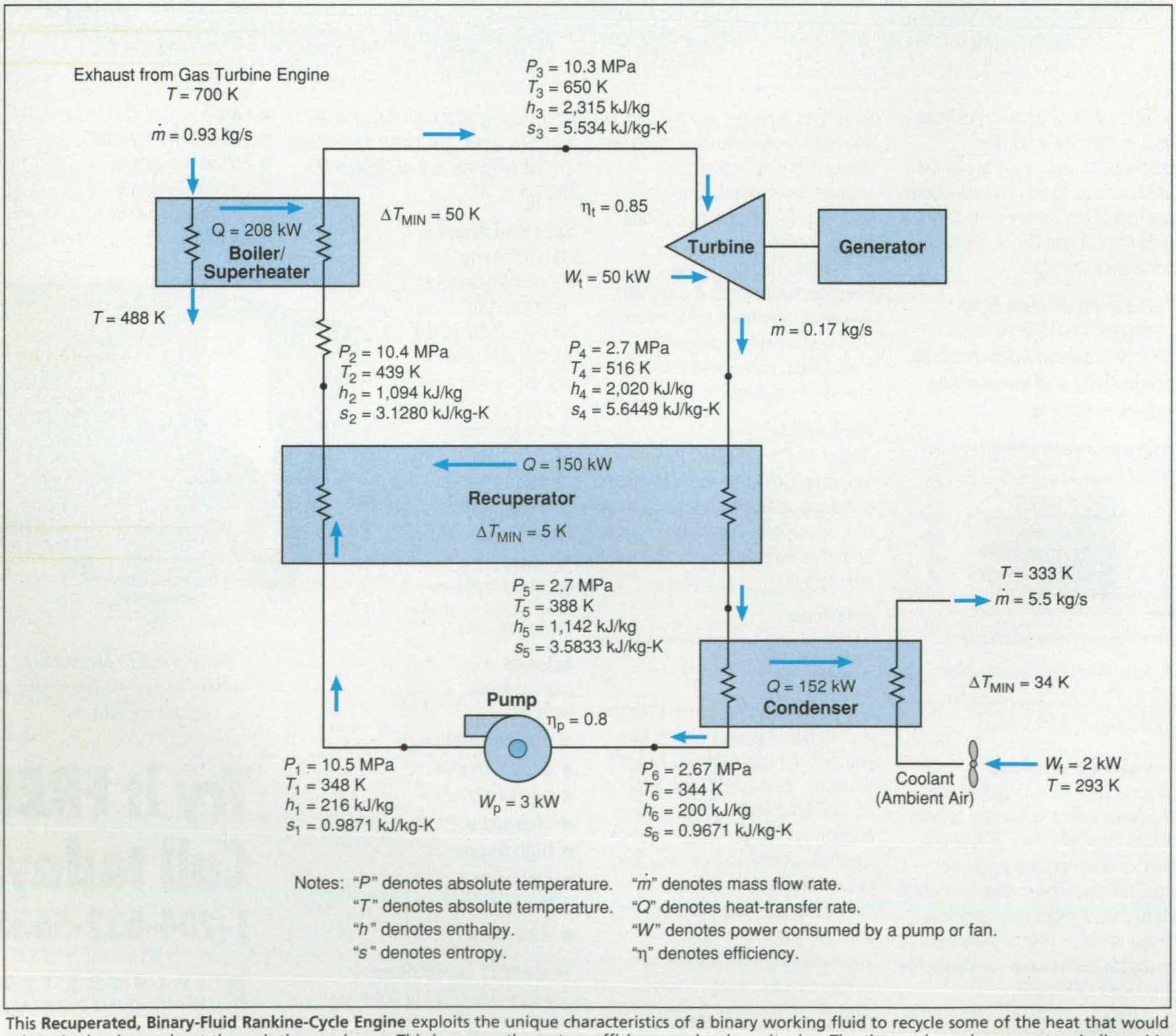
Compact, Recuperated, Binary-Fluid Rankine-Cycle Engine

The primary advantages of this engine are compactness and relatively high energy-conversion efficiency.

John H. Glenn Research Center, Cleveland, Ohio

A Rankine-cycle engine that contains a binary working fluid (ammonia + water) and a recuperative heat exchanger has been built and tested. This engine is a prototype of "bottoming"-cycle engines that would be used to extract additional useful power from the exhaust heat of gas turbine engines. Its advantages are well suited to vehicles, where volume and weight are important constraints.

The described binary-fluid Rankine cycle has higher efficiency and smaller volume than Rankine cycles with single-component working fluids. It has nearly the same efficiency but much smaller volume than the binary-fluid Kalina Rankine cycle, which entails the use of separators and additional heat exchangers to vary the proportions of ammonia and water in the working fluid at various points in the cycle. The present cycle does not vary the composition of the working fluid. Because the separators and additional heat exchangers are not needed, an engine based on the present recuperated, binary-fluid Rank-



This **Recuperated, Binary-Fluid Rankine-Cycle Engine** exploits the unique characteristics of a binary working fluid to recycle some of the heat that would otherwise be dumped out through the condenser. This improves the system efficiency and reduces its size. The thermodynamic parameters indicated in the figure were calculated for a working fluid of 80 weight percent ammonia and 20 weight percent water.

ine cycle has only a fraction of the volume of the corresponding Kalina-cycle system.

The present recuperated, binary-fluid, Rankine-cycle engine (see figure) includes a boiler/superheater, a turbine that drives an electric-power generator, a condenser, a pump, and a recuperative heat exchanger ("recuperator" for short). The boiler/superheater transfers heat from the gas-turbine exhaust or other source to the working fluid. The turbine extracts useful power from the heat in the working fluid. The condenser removes the final waste heat that is of too low a temperature to be worth recovering. The recuperative heat exchanger transfers heat from the turbine-outlet/condenser-inlet junction (a higher-temperature, lower-pressure location) to the pump-outlet/boiler-inlet junction (a lower-temperature, higher-pressure location). In so doing, the recuperator recycles some of the heat that would otherwise be dumped out through the condenser as waste heat; thus, the main effect of the recuperator is to increase the energy-conversion efficiency.

A large variation (≈100 K) in the saturation temperature of the ammonia/water mixture with the vapor fraction during boiling makes recuperation possible in this cycle. In designing the recuperator, one must consider the details of heat transfer and the behavior of the binary working fluid. The flow on the low-temperature side of the recuperator proceeds through the sequence of single-phase liquid, two-phase boiling, and superheated vapor. On the high-temperature side of the recuperator, the flows at the corresponding positions in the recuperator may be two-phase condensing or superheated vapor. Thus, the operation of the recuperator entails several different two-phase heat-transfer phenomena, all of which must be taken into account.

Both theoretical calculations and experiments have shown that this recuperated, binary-fluid Rankine-cycle engine operates with energy-conversion efficiency 1.5 or 2.0 times that of an otherwise identical engine that contains either ammonia (only) or water (only) as the working fluid. It has also been found that the total volume of the three heat exchangers (the boiler/superheater, the condenser, and the recuperator) in this engine is 10 percent less than the total volume of the two heat exchangers (the boiler/superheater and the condenser) for a nonrecuperated engine using the binary fluid at the same source and sink temperatures.

This work was done by Christopher J. Crowley and Martin A. Shimko of Creare, Inc., for **Glenn Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16834.

Vortex-Fired Liquid-Fuel Rocket Combustion Chambers

Swirling cold propellants and pressure gradients keep hot gases away from walls.

Marshall Space Flight Center, Alabama

Liquid-fuel rocket engines that utilize vortex flow fields to keep combustion-chamber walls cool have been investigated in computational simulations and experiments. In an engine of this type, the vortex flow establishes radial gradients of pressure and density that cause the lower-density hot combustion products to be confined near the central axis of the combustion chamber while cold gases yet to be burned are centrifuged to

the combustion-chamber wall. Keeping combustion-chamber walls cool in this manner reduces or eliminates damage by heat and oxidation, thereby (1) eliminating the need for leak-prone cooling passages, (2) extending the operational lifetimes of combustion chambers, and (3) creating an opportunity to fabricate combustion-chamber walls more easily, using relatively inexpensive materials (possibly even lightweight composite materials) instead of expensive alloys.

For the most part, the combustion chamber in an engine of this type has a conventional appearance: it includes a head-end dome, a barrel section, and a section that converges from the barrel to a throat that opens into an expansion bell. A vortex flow field with a co-swirling, counter-flowing character is produced in the following way: One of the propellants (typically, oxygen at supercritical pressure) is injected circumferentially tangential through ports just forward of the junction between the barrel and the section that converges to the throat. The other propellant (typically, liquid hydrogen) is injected either from the head end or through a porous liner in the chamber wall.

The circumferential component of the injection flow forms a free vortex that spirals forward along the wall of the barrel to head end, where it turns inward to form a second vortex, concentrated along the axis, that flows out of the chamber at the aft end. If the fuel is fed through the wall, the upwelling oxygen burns the incoming fuel and carries it forward and into the axial vortex. If the fuel is injected from the head end, then it burns only along the axis. In both fuel-injection schemes, the radial gradients of pressure and density prevent hot combustion products from migrating out to the wall. Instead, the hot gases are buoyed toward the axis. Thus, the wall stays cool.

The propellant injectors can be relatively simple because unlike in other rocket engines, there is no need to atomize or mix the propellant fluids immediately upon injection. All of the necessary atomization and mixing is effected by the coaxial vortex flow. Yet another advantage of engines of this type is that they appear to be immune to combustion instability.

This work was done by William H. Knuth, Martin Chiaverini, and Daniel J. Gramer of Orbital Technologies Corp. for **Marshall Space Flight Center.** *For further information, please contact the company at knuthw@orbitec.com.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Orbital Technologies Corporation
1212 Fourier Drive
Madison, WI 53717

Refer to MFS-31477, volume and number of this NASA Tech Briefs *issue, and the page number.*

Systems for Dynamic Control of Growth of Protein Crystals

Key parameters that affect crystallization can be monitored and controlled.

Marshall Space Flight Center, Alabama

Computer-controlled laboratory apparatuses for real-time monitoring and control of the growth of protein crystals are undergoing development. By use of an apparatus of this type, one can monitor and control several parameters that

affect the growth of protein crystals; these parameters include temperature, pH, ionic strength, concentration of solute, rate of change of concentration of solute, and possibly others. One can utilize the monitoring capabilities to make decisions on the basis of the measured parameters. One can utilize the control capabilities to effect precise control of growth; one can also start, stop, or reverse growth at will.

In a representative apparatus of this type, precipitating solutions are mixed in a plastic crystallization chamber. The apparatus includes two syringes connected to the crystallization chamber via plastic tubes. By use of a stepping motor that drives a shuttle, the plunger of one syringe is driven in the emptying direction, while the plunger of the other syringe is driven in the filling direction. Probes to monitor electrical conductivity (as an indication of concentration), pH, ionic strength, and temperature are incorporated into the crystallization chamber. Temperature can be controlled by use of a Peltier-effect (thermoelectric) incubator unit. Electronic circuits for controlling the motor, controlling the temperature, and converting the probe outputs into a digital form readable by the associated computer are contained on a printed-circuit board.

An apparatus of this type can be assembled in building-block fashion: Optionally, it can be constructed without the probes and associated circuitry, which can be added later. Another conceptual variation of the basic design would be a multiplexing design in which multiple syringes, multiple motor drives, and/or a manifold and valves would be used to control flows to multiple crystallization chambers so as to test multiple values of molarity and multiple rates of change of molarity of the crystallizing protein.

This work was done by Leonard Arnowitz and Emanuel Steinberg of BioSpace International, Inc., for **Marshall Space Flight Center.** *For further information, please contact the company at bsi@biospace11.com.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to MFS-31400, volume and number of this NASA Tech Briefs *issue, and the page number.*

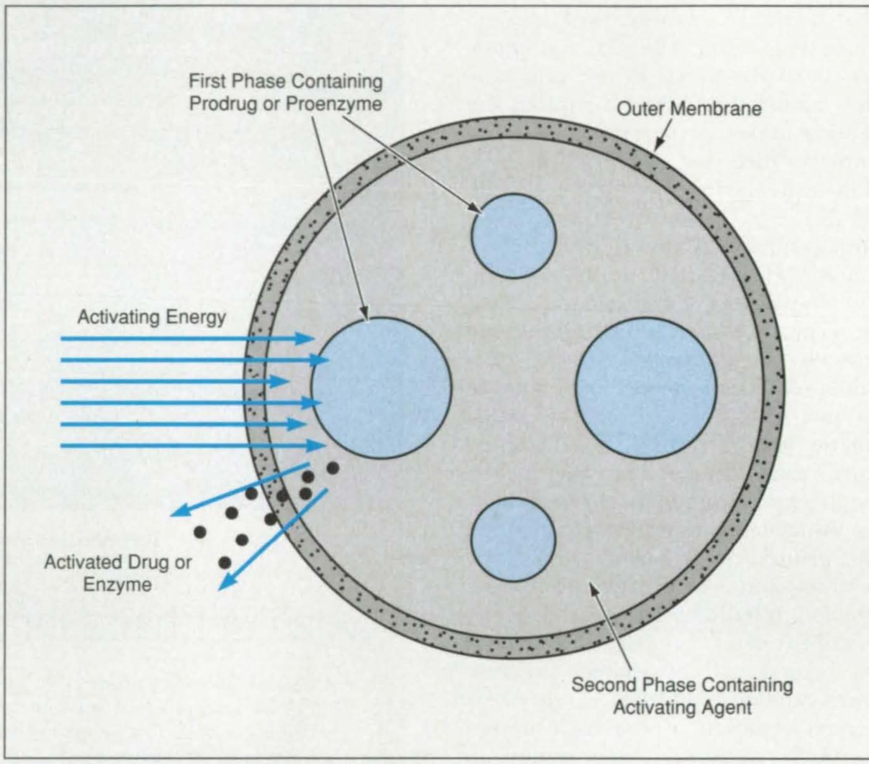
In Situ Activation of Microencapsulated Drugs

Activation could be effected by thermal, electromagnetic, ultrasonic, and/or other forms of energy.

Lyndon B. Johnson Space Center, Houston, Texas

In a new method of delivering drugs to target sites in a human body, (1) the drugs would be stored in inactive forms in timed-release microcapsules that would be injected, then (2) the drugs would be activated by exposing the target sites to suitable forms of penetrating energy that could include electromagnetic radiation (radio waves, light, or x rays), ultrasound, or heat, then (3) the drugs would diffuse out of the microcapsules. The method would be well suited for drugs that have short shelf lives in their active forms and/or could be activated at target sites upon exposure to nonharmful activation energy.

The concept of microencapsulation of drugs was reported in "Microencapsulation of Multiple Drugs" (MSC-22489), *NASA Tech Briefs*, Vol. 20, No. 11 (November 1996), page 92. To recapitulate: microcapsules are formed as multilammelar, multiple-immiscible-phase structures that include alternating hydrophilic and hydrophobic liquid layers surrounded by flexible, semipermeable, polymeric outer membranes. The skins are designed to allow sustained diffusion of the bioactive drugs out of the microcapsules.



A Microcapsule Would Contain Immiscible Liquid Phases, the first phase consisting of spheroids containing a prodrug or a proenzyme, the second phase being the surrounding liquid containing an activating agent. Exposure to electromagnetic or ultrasonic energy would cause activation, after which the drug would diffuse through outer membrane to act on surrounding tissues.

The disadvantage of conventional liposomes and of previously developed microcapsule drug-delivery systems is that they are impractical for delivery of drugs that are chemically labile or that have short shelf lives in their bioactive forms. Typically, a liposome or a previously developed microcapsule does not contain both a drug precursor and activator; consequently, the contents of the microcapsule cannot be converted to the active form of the drug immediately before or after administration to the patient. Also, conventional microcapsules cannot be lysed *in situ* to release bioactive drugs at target tissue sites without deposition of large amounts of energy that could adversely affect the tissues.

A microcapsule for use in the proposed method (see figure) would include a spherical drug-permeable outer membrane that would enclose immiscible fluid compartments containing the drug precursor in one phase and an activating agent in another phase. The activating agent would be a substance that could be activated by one of the forms of energy mentioned above and that would, in turn, react with the drug precursor to produce the active form of the drug. Such microcapsules would have to be protected from the activating form of energy during storage and until the time of administration to a patient.

Depending on the depth of the target site in the patient's body, the activating energy could be delivered from a transducer on the outside or, if necessary, from the inside by use of a catheter that contains a fiber-optic probe, ultrasonic or electromagnetic transducer, or other device. In a variation of the basic concept, the activating energy could also be utilized to stir the precursor and activator liquid phases together. In another variation, the activating agent could be contained within a thermosensitive membrane that could be ruptured to release the activating agent. Numerous other variations can readily be envisioned.

This work was done by Dennis R. Morrison of **Johnson Space Center** *and Benjamin Mosier of Institute for Research, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Bio-Medical category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22866.

Books & Reports

Spaceborne Telescope for Communication, Ranging, and Imaging

A report describes a program to develop a multi-function telescope to be carried aboard spacecraft of the planned X2000 series of planetary missions. [A related multi-function telescope was described in "Telescope for Imaging and Laser Communication" (NPO-20388), *NASA Tech Briefs*, Vol. 24, No. 1 (January, 2000), page 27a.] An important element of this program is minimization of instrument mass through combination of several optoelectronic subsystems into one telescope system with one aperture for transmission and reception of light. The functions to be performed by the telescope system include scientific imaging, reception of laser-altimeter return signals, and two-way optical communication. The communication functions include transmission of scientific data, reception of commands, and reception and retransmission of laser ranging signals. For communication, the telescope would be aimed at the sunlit Earth, by use of aiming techniques like those summarized in the cited previous article. Rates for transmission of scientific data to Earth from as far away as Jupiter would range from 100 kb/s (day) to 400 kb/s (night). The data rate for reception of commands from Earth would be 2 kb/s. A flight-qualified engineering model of the system is scheduled for completion in the year 2001.

This work was done by James Lesh and Hamid Hemmati of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Laser Communications Terminal for the X2000 Series of Planetary Missions," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Technology Reporting Office
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Mail Stop 122-116
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20425, volume and number of this NASA Tech Briefs *issue, and the page number.*

Dislocation-Induced Changes in $In_xGa_{1-x}As$ Quantum Dots

A report describes an experimental investigation that revealed a previously unknown type of spatial alignment of quantum dots (QDs) in $In_xGa_{1-x}As$/GaAs multilayer structures. Multilayer

arrays of QDs (in the form of nanometer-sized $In_xGa_{1-x}As$ islands) were formed by alternately depositing 10-nm-thick layers of GaAs and 5-molecule-thick layers of $In_{0.6}Ga_{0.4}As$/GaAs on substrates of semi-insulating [001] GaAs with a 2° miscut toward the [101] direction (resulting in steps along the [010] direction). Specimens were examined by electron microscopy and cathodoluminescence (CL) spectroscopy. The QDs were observed to undergo a transition between step edge alignment along the [010] direction to counter step alignment (along the [100] direction). This transition apparently occurred when (or soon after) the fifth quantum-dot layer was deposited, and is apparently associated with the onset of a network of misfit dislocations at the $In_{0.6}Ga_{0.4}As$/GaAs interface. A change to larger QDs in smaller concentrations was also observed after formation of the network of dislocations. Strong near-infrared CL emission from the QDs was observed, despite the presence of dislocations.

This work was done by Rosa Leon of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Dislocation-induced Changes in Quantum Dots: Step Alignment and Radiative Emission," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
NPO-20695

Solitons on WDM Beams in a Nonlinear Optical Fiber

This paper sets the ultimate limit on the maximum amount of optical data pulses that can be sent through a single fiber in a given period under the wavelength-division-multiplexed (WDM) format. The discovery in 1973 that optical soliton on a single wavelength beam can exist in fiber is one of the most significant events since the perfection of low-loss optical fiber communication. This means that, in principle, data pulses may be transmitted in a fiber without degradation forever. This soliton discovery sets the ultimate goal for optical fiber communication on a single-wavelength beam. Another most significant event is the development of WDM transmission in a single-mode fiber. This means that multiple beams of different wavelengths, each carrying its own data load, can propagate simultaneously in a single-mode fiber. This WDM technique provides dramatic increase in the bandwidth of a fiber. However, due to the presence of complex nonlinear co-propagating pulses on different wavelength beams, it is no longer certain that WDM soliton can exist. The existence of solitons is a blissful event in nature. It is a marvel that the delicate balance between the dispersion effect and the nonlinear effect can allow a specially shaped optical pulse to propagate in the fiber without degradation. They occur only on single-wavelength beams. When beams with different wavelengths co-propagate in a single-mode fiber, such as in the WDM case, interaction of pulses on different beams via the nonlinear cross-phase-modulation (CPM) effect (the Kerr effect) is usually instrumental in destroying the integrity of solitons on these wavelength multiplexed beams. This paper shows that temporal solitons can exist on WDM beams in a single fiber under appropriate conditions. The existence of these solitons critically depends on the presence of the nonlinear CPM effect of the WDM beams. Just as the earlier single-beam soliton case, this discovery sets the ultimate goal for optical fiber communication on WDM beams.

This work was done by Cavour Yeh and Larry Bergman of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The Existence of Optical Solitons on Wavelength Division Multiplexed Beams in a Nonlinear Fiber," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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(818) 354-2240

Refer to NPO-20772, volume and number of this NASA Tech Briefs *issue, and the page number.*

Fast Observers for Spacecraft Pointing Control

A report discusses the design of fast stochastic observers for spacecraft pointing control. In this special context, "observers" signifies mathematical algorithms, implemented on computers aboard spacecraft, through which one processes sensory data (principally, the outputs of star trackers and gyroscopes) to estimate the states (atti-

tudes and angular velocities) of the spacecraft. The development in the report was motivated by the presence of an attitude-dependent bias error in the star-tracker measurement associated with NASA's upcoming SIRTF (Space Infra-Red Telescope Facility) space telescope. This attitude-dependent bias term lies outside of basic linear estimation assumption, and the well-established Kalman theory is no longer optimal. The attitude-dependent bias term forces a step response through the dynamics of the onboard estimator each time the spacecraft is repositioned. If an optimal Kalman filter were used, its sluggish dynamics would create a long undesirable lingering output drift in the pointing response. While this drift error is small (e.g., at the arcsecond level) it cannot be ignored for space telescope applications, and is the main reason that Kalman filters are routinely replaced by simple observers on important missions with stringent pointing requirements such as the Hubble Space Telescope and SIRTF.

In this report, a theoretical analysis of an attitude estimator comprising three decoupled single-axis observers leads to a globally optimal solution for designing a constrained stochastic observer of second-order form. This stochastic observer minimizes the variance of the attitude estimate, subject to a constraint that its poles lie to the left of a specified vertical line in the complex Laplace-transform s-plane. This so-called "fast observer" design allows the step response of the onboard estimator to be sped up with minimal degradation in the variance of the state estimate. Examples are presented to illustrate the optimal tradeoff between observer speed and estimation error.

This work was done by David S. Bayard of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Fast Observers for Space Telescope Pointing Control with Application to SIRTF," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*
NPO-20883

Nesting-Hoop Solar Sail

A report discusses a proposed nesting-hoop solar sail that would be used to propel a spacecraft on a deep-space mission. The nesting-hoop design concept was chosen as one that would afford a desired combination of small mass and compact stowage during launch. The sail would include multiple disks, each comprising a thin fabric stretched over a hoop of wire or thin tubing (e.g., hypodermic-needle tubing). The adjacent hoops would be bonded together by springy extensions that would be fabricated in their sail-deployed positions. The sail would be stowed by folding at the springy extensions. Successive hoops would be progressively slightly smaller so that when stowed, the hoops would nest and therefore the thickness of the stowed sail would be approximately proportional to the thickness of the fabric (instead of the much greater thickness of the hoops). The fabric would not be folded for stowage; consequently, the spring tension (and thus the required thickness of the hoops) needed to keep the fabric from wrinkling could be kept to a minimum. The sail would be deployed by allowing it to unfold under its own springiness.

This work was done by Brian Wilcox of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Nesting-Hoop Solar Sail," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*
NPO-20879

Special Coverage: Semiconductors/ICs

Parallel Integrated Frame Synchronizer Chip

This chip can handle data in a variety of formats at rates up to 500 Mb/s.

Goddard Space Flight Center, Greenbelt, Maryland

The Parallel Integrated Frame Synchronizer (PIFS) chip is one of three very-large-scale integrated (VLSI) circuits designed for ground processing of streams of telemetric data received from spacecraft. These application-specific integrated circuits (ASICs) are the main components of a developmental advanced telemetric-data-processing system that is intended to be smaller, cheaper, and more capable than its predecessors. Each of these ASICs is intended to perform most of the functions heretofore performed by multiple integrated circuits on printed-circuit cards. These ASICs are designed mainly to accommodate the packet-telemetry-data protocols recommended by the Consultative Committee for Space Data Systems (CCSDS); however, they also have generic capabilities in that they are programmable and can therefore also be made to handle telemetry in special data formats.

The three ASICs are used in return-link processing, which is the digital processing that takes place after the reception, demodulation, and digitization of signals transmitted from spacecraft. The return-link processing functions are apportioned sequentially among the three ASICs as follows:

1. The PIFS chip delineates frames of data from the incoming serial bit stream by implementing a sophisticated algorithm that searches for frame synchronizers, which are prescribed bit sequences placed at the frame boundaries.
2. The output of the PIFS chip is fed to the second ASIC, which is the Reed-Solomon Error Correction (RSEC) chip. For powerful protection against errors that can enter both the data and the protocol structures, the data frames are Reed-Solomon encoded, with interleaving, prior to transmission from the spacecraft. The RSEC decodes and de-interleaves the data and corrects any Reed-Solomon-correctable errors.
3. The output of the RSEC chip is fed to the third ASIC, which is the CCSDS Service Processor chip. This chip demultiplexes, extracts, and validates user data from the composite stream of telemetry frames.

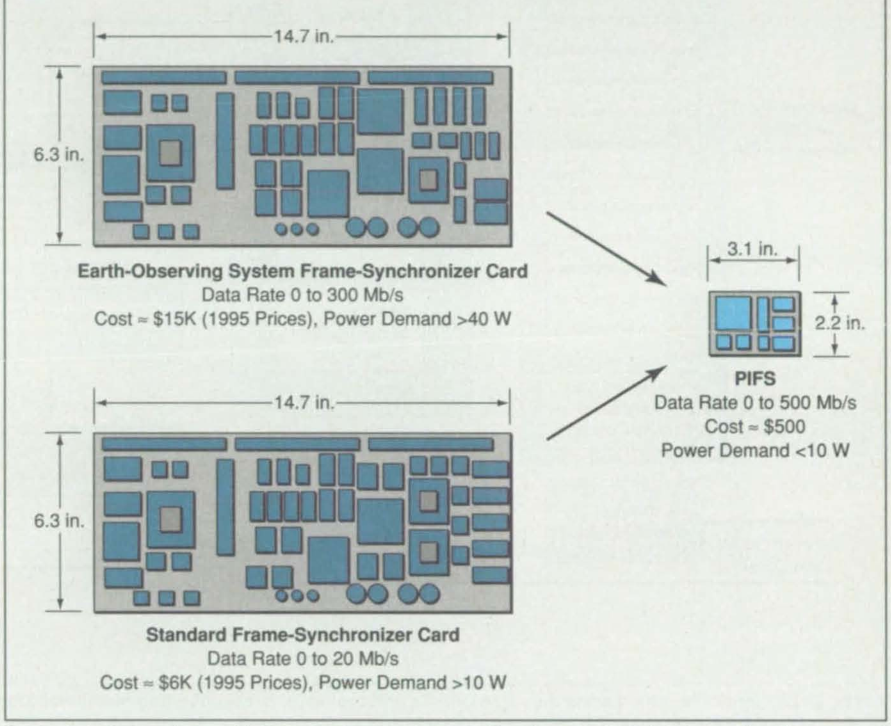


Figure 1. In **Comparison with Prior Frame-synchronizer Circuitry**, the PIFS chip is smaller, cheaper, and more capable.

The PIFS chip is a complementary metal oxide/semiconductor (CMOS) gate array laid out according to 0.6-μm design rules. As its name indicates, the PIFS chip implements a parallel-processing algorithm for synchronization of telemetry frames. Parallel processing requires logic circuitry significantly more complex than that required for serial processing; however, because advances in VLSI have greatly reduced the costs and sizes of logic circuits, the greater complexity of the PIFS design is no longer a disadvantage. As shown in Figure 1, the PIFS chip is much smaller than two older multiple-VLSI-chip serial-processing frame synchronizers that it is intended to replace.

The PIFS chip is controlled by a set of internal registers that are configured through a standard microprocessor interface (see Figure 2) prior to operation. The registers afford the programmability that enables the PIFS to satisfy the frame-synchronization requirements of many different spacecraft missions. During operation, data enter the chip in one of two ways:

- If the data rate is very high, the serial data stream is first externally converted to a byte-wide parallel data stream and then fed into an internal first-in/first-out (FIFO) memory.
- If the data rate is <50 Mb/s, the serial data stream can be fed directly to the PIFS and converted to parallel internally.

The FIFO memory enables the logic circuitry within the PIFS to be synchronized with a separate master clock; this feature, in combination with a data-flow architecture, offers several advantages over older frame synchronizers, including lower latency, easier processing of nested or asynchronously blocked data, and automatic pipeline flushing. As data pass through the chip, correlations are

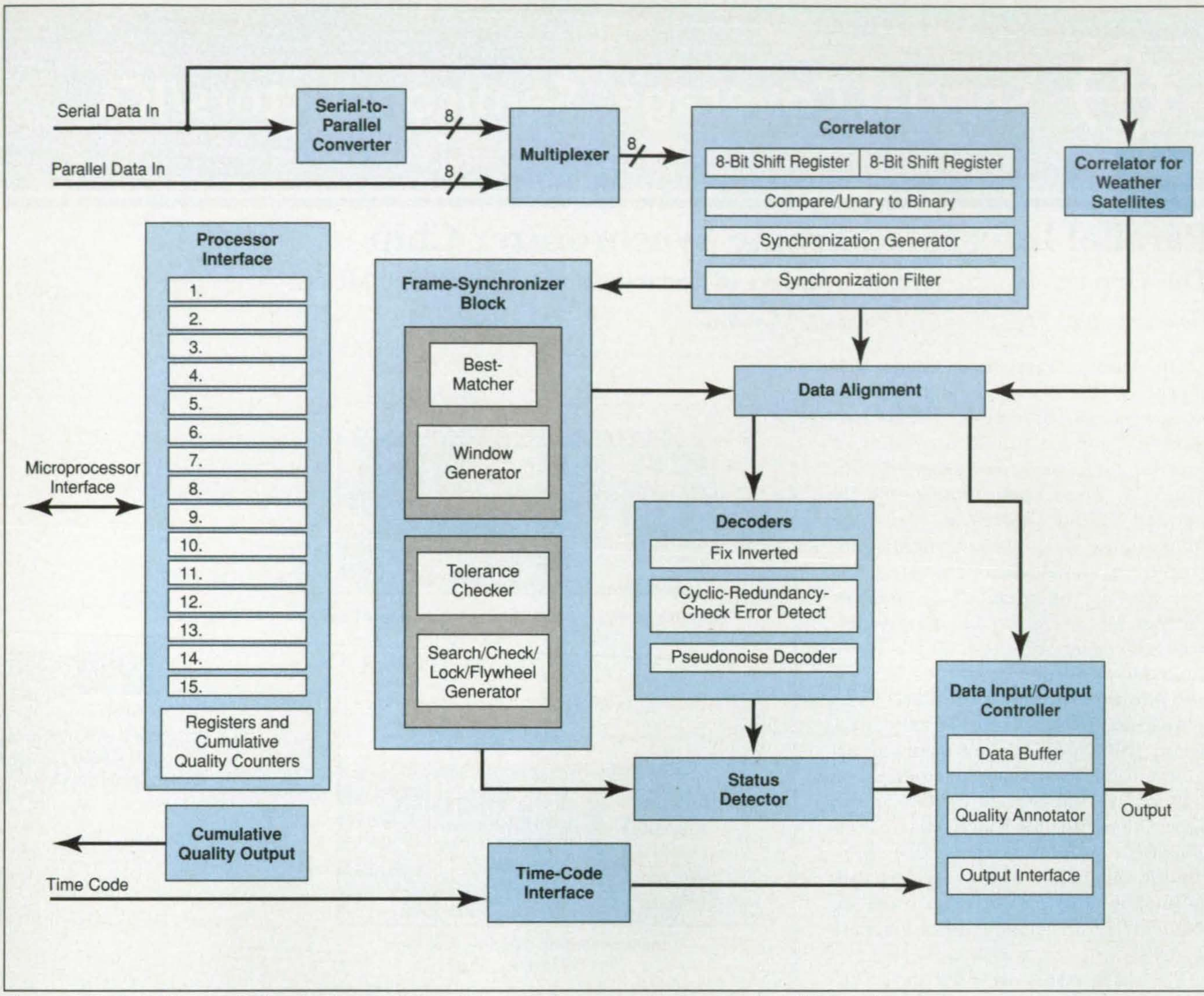


Figure 2. This **Block Diagram** depicts the flows of data and the major data-processing functional subdivisions of the PIFS.

computed, locations of synchronizers are calculated, and data are aligned to frame boundaries. The PIFS chip performs a superset of the functions of prior frame synchronizers, including cumulative quality accounting, time stamping, real-time quality trailer generation, and capability to synchronize all current weather-satellite formats. One exception is reverse data handling, which is expected to become unnecessary because of the planned ubiquitous use of solid-state recorders aboard spacecraft.

This work was done by Parminder S. Ghuman and Toby Bennett of **Goddard Space Flight Center** *and Jeff Solomon formerly of RMS Technologies. For further information, access the Technical Support Package (TSP) free on-line at www.nasatech.com under the Electronic Components and Systems category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13813.

CMOS APS With Integrated Centroid-Computation Circuits

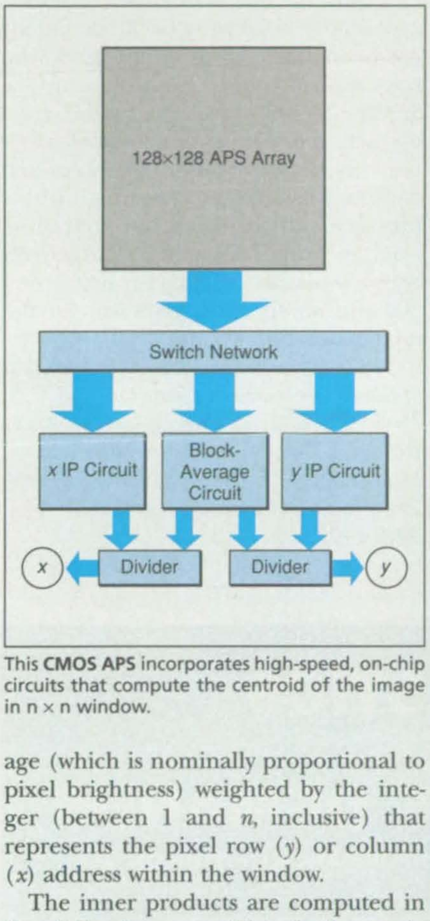
Power consumption, latency, and size can be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

An advanced complementary metal oxide/semiconductor (CMOS) active-pixel sensor (APS) incorporates integrated circuitry that computes the centroid of the image in a window selectable by the user. The development of this circuitry is significant in that it is necessary to compute centroids of images in diverse applications that include robotic vision, autonomous navigation, optical communications, and scientific imaging. Heretofore, it has been necessary to compute centroids by use of off-chip circuitry, at the cost of increased data latency, power consumption, and system size. This circuitry computes image centroids on-chip at a high speed and in analog domain, while consuming little additional power, and is compatible with high-performance CMOS APS circuitry.

The prototype window-centroiding CMOS APS contains a 128 × 128-pixel APS with its readout circuitry, plus the centroid processor, which includes a

switching network, analog inner-product (IP)-computing circuits, and an analog divider (see figure). The centroid computer operates on a window of $n \times n$ pixels, where $3 \leq n \leq 9$ to produce both x and y centroids. Computation of the centroid involves the computation of inner products (weighted sums) and division of the weighted sums by an overall nonweighted sum. Each term in each inner product is proportional to a pixel volt-



This **CMOS APS** incorporates high-speed, on-chip circuits that compute the centroid of the image in n × n window.

age (which is nominally proportional to pixel brightness) weighted by the integer (between 1 and n, inclusive) that represents the pixel row (y) or column (x) address within the window.

The inner products are computed in the following way: Timed electronic switches are used to sample the pixel voltages to separate sampling capacitors, the sizes of which are proportional to the integer row and column addresses. The row and column inner products are obtained by simultaneously dumping the charges on the corresponding sampling capacitors into analog charge-summing circuits. Finally, by use of a single divider circuit, the row and column inner products are divided by scale factors proportional to the nonweighted sum of pixel voltages in the window to obtain the x and y centroid values. These computations are performed in column-parallel fashion, so that centroids are computed at the row-readout rate, enabling high-speed, low-power centroid computation.

In tests, centroid errors were determined for various image brightnesses and various sizes and locations of windows; the errors were found to range from about 0.02 pixel over most of the APS array to a worst-case value of about 0.07 pixel for a 3 × 3 window. Overall, the results of the tests were interpreted as signifying that one can determine centroids to within 0.05 pixel under most lighting conditions while operating at the update rates used in the tests (20 to 50 kHz).

This work was done by Bedabrata Pain, Chao Sun, and Guang Yang of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Technology Reporting Office
JPL
Mail Stop 122-116
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20715, volume and number of this NASA Tech Briefs *issue, and the page number.*

Software for Designing Plasma Reactors for Microelectronics

Ames Research Center, Moffett Field, California

Outer-space plasmas and arc-jet plasmas are well known to many researchers at NASA. Efforts to understand the structures of these plasmas have consumed years of research at various NASA laboratories. Computational modeling of such plasmas involves analyses of multicomponent, multitemperature flows, and many computer codes developed by NASA are available for this purpose. Now, researchers at Ames Research Center have applied their expertise to understand a different kind of plasma — the kind used in manufacturing integrated circuits.

Typically, in such manufacturing, a weakly ionized plasma is used to etch fine patterns (smallest dimensions of the order of 10^{-7} m) in a silicon wafer. The discharge gas (the gas used to generate the plasma) could be chlorine or some type of fluorocarbon, depending on the material to be etched or the required functionality. The objective is to obtain a highly directional (even vertical) etched profile at a rapid rate, with minimum use of chemicals. If one were to use the chemicals in their liquid form — in what is known as "wet etching" — this objective would be compromised. Because chemical etches are "directionally blind," wet etching results in isotropic features. In contrast, dry etching with the help of a plasma achieves desired directionality through the combined action of reactive atoms or radicals and vertical bombardment of the surface with ions to clear off chemical-reaction products.

It is of interest to the microelectronics community to understand this dry process in order to optimize the process and design the right kind of reactor. That is where computational modeling is valuable. A computer code called Semiconductor Equipment Modeling Software (SEMS) has been developed to enable such modeling. This program solves equations of multicomponent, multitemperature, chemically reacting flows. The set of equations includes the Navier-Stokes equations of subsonic flow of gases, a gas-energy equation, an electron-energy equation, multicomponent conservation-of-chemical-species equations, and Maxwell's equations for determining the power coupled to the plasma from an inductive coil or other external power source.

The coupling of several such equations with disparate time scales results in a stiff (in the mathematical sense) problem. Time scaling of the equations has been explored in an effort to find ways to solve the problem rapidly. SEMS has been used to model commercial reactors and processes common in the fabrication of integrated circuits. Results have been obtained for nitrogen, chlorine, carbon tetrafluoride, and other plasmas in inductively coupled plasma reactors for processing 300-mm wafers in preparation for the next-generation circuits.

This program was written by Deepak Bose of Eloret Thermosciences Institute and T. R. Govindan and M. Meyyappan of **Ames Research Center.** *For further information, please contact M. Meyyappan at (650) 604-2616 or meyya@orbit.arc.nasa.gov.*
ARC-14531

Writing Circuit Patterns by Use of Scanning UV Lasers

Prototype circuits can be fabricated rapidly.

NASA's Jet Propulsion Laboratory, Pasadena, California

Scanning ultraviolet (UV) lasers would be used to expose ultraviolet-sensitive photoresists to form patterns of conductors for electronic circuits, according to a proposal. Heretofore, such patterns have been formed by exposing photoresists to collimated ultraviolet or visible light through contact or proximity photomasks. The use of scanning lasers would make it unnecessary to make or use masks, and it would be amenable to rapid fabrication of prototype circuits.

In forming a given circuit pattern, the scanning of the ultraviolet laser would be controlled by use of the same plotting data, generated by computer-aided-design software, that would otherwise have been used to plot the photomask for the pattern. In the case of a negative photoresist, the portion of the resist not exposed to the laser would be removed by a stripping compound after the photoresist had been developed. The metal underlying the exposed and stripped areas would be etched away. Then the remaining exposed photoresist would be stripped away.

In the case of a positive photoresist covering a very thin chromium-coated medium (insulating substrate), the part of the resist exposed by the laser would be removed by developing and stripping, then through the resulting openings in the resist, the desired electrically conductive material (typically, copper or gold) would be electrodeposited through the openings in the resist. Finally the unexposed resist and the thin chromium coat would be stripped from the medium.

This work was by Frank Hartley and Steve Bolin of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Manufacturing/Fabrication category.*
NPO-20495

New on the MARKET

Digital Oscilloscope

Gould Instrument Systems, Valley View, OH, offers the Ultima 500 digital storage oscilloscope, which combines the acquisition capabilities of a 4-channel DSO with the features of a PC to simplify data handling by moving from capture to report in one unit. The scope provides a range of real-time analysis capabilities including FFT, differentiation, integration, graphing, histogram, phase correction, and math functions. User-defined real-time measurements can be developed using the on-board formula editor. Up to eight display windows can be viewed at once, and display capabilities include YT, XY, simultaneous YT and XY, persistence, and envelope. Ultima is supported with a package of trigger tools to qualify incoming signals for amplitude, time, pulse, gating, and TV. **Circle No. 732**

Mechanical Encoder

The CLAROSTAT division of Invensys Sensor Systems, El Paso, TX, has introduced the Model 510 mechanical encoder for applications including volume control, motor control, low-end instrumentation, and other position controls. Digital output is produced by a position-sensing element available with a 2-bit gray code in options of 4, 6, or 9 cycles-per-revolution, and a 4-bit gray code absolute encoder with 16 positions. The 2-bit gray code encoders also are available without detents at up to 128 ppr. Options include mounting brackets, custom shaft lengths, lead configurations, and connectors. **Circle No. 733**

Data Acquisition Board

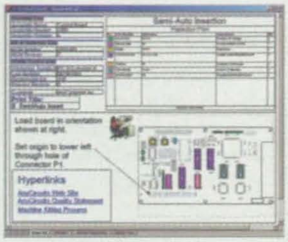
The DAP 840/103 PCI DAP board for 32-bit real-time data processing has been introduced by Microstar Laboratories, Bellevue, WA. The board acquires data with 14-bit resolution, and has onboard intelligence implemented as DAPL 2000, a 32-bit multi-tasking, real-time operating system that runs on an onboard processor. The board features eight onboard analog inputs, two onboard analog outputs, eight onboard digital inputs and eight onboard digital outputs. It has 8 MB of onboard memory for data buffers, and uses DMA bus-mastering to transfer to the PC from onboard memory. The board provides 14-bit A/D resolution for its 16 onboard analog inputs, and 12-bit resolution for its two onboard analog outputs. **Circle No. 734**

Conductivity Meters

OAKTON Instruments, Vernon Hills, IL, offers the Acorn Con 5 portable conductivity meter, and the Acorn TDS 5 Total Dissolved Solids (TDS) meter. The meters feature microprocessor technology for user temperature readouts within ±0.5°C accuracy, automatic temperature compensation, auto-ranging, pushbutton calibration hold, automatic shut-off, and self-diagnostic error messages. The Acorn TDS readings are in ppm and ppt units up to 9.99 ppt, and the unit offers a selectable conductivity-to-TDS conversion factor. The Acorn Con 5 gives readings in uS and mS units up to 19.99 mS. **Circle No. 735**

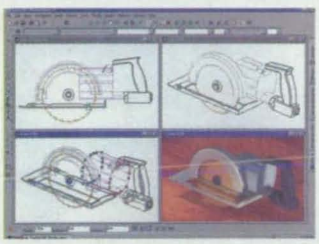
New on DISK

Assembly Documentation



Aegis International Software Corp., Philadelphia, PA, has introduced the CircuitCAM Assembly Documentation module that converts CAD and BOM data into documentation for printed circuit board assemblers. The module is a tool for converting design and BOM data into inspection and assembly aids from board level through final assembly. The Windows-based module supports OLE, video, audio, and hypertext linking to the Internet and corporate Intranets. It employs user-definable, color-coded outputs for engineering changes. The module also assists marketing and communication of assembly information. **Circle No. 725**

2D/3D CAD Software

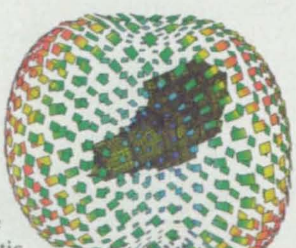


IMSI, Novato, CA, has released TurboCAD® Professional v6.5 2D/3D CAD software that offers Microsoft® VBA programming technology to automate repetitive tasks, and Lightwork® technology for visualization of 3D objects. New features include 2D Boolean tools, geometric alignment aids, and 25 distinct file formats. It also allows users access to millions of drawings on the Internet, to create symbol libraries, and to share drawings with other CAD products using the AutoCAD 2000 DWG/DWF File Sharing feature. New 2D modifying tools and 3D primitive tools have been added. **Circle No. 727**

Semantic Processing Technology

CoBrain 2.0 semantic processing software from Invention Machine Corp., Boston, MA, reads documents and extracts key concepts by analyzing sentence structure. It organizes and creates content for web portals, and automatically generates subject categories based on documents read. This version features a capability to automatically generate knowledge bases for Enterprise Knowledge Portals, business-to-business, and consumer web sites. CoBrain can structure a corporate knowledge base, allowing knowledge to be shared across the enterprise, and ensuring the identification and retention of intellectual property. **Circle No. 728**

Vibro-Acoustic Design



LMS, CAE Division, Troy MI, offers LMS SYSNOISE Rev 5.5 vibro-acoustic design software that features modules and enhancements for noise and vibration analysis. Three new modules are available with the revised product, and are based on the concept of Acoustic Transfer Vectors. The new modules include numerical engine acoustics, inverse numerical acoustics, and panel acoustic contribution analysis. Enhancements include faster solution times, memory allocation, binary-compatible databases, FlexLM licensing mechanism, peak value contour plotting, integrated contour plotting, complex mass density, frequency dependent mass density, and speed of sound for all modules. **Circle No. 729**

New LITERATURE

Fiber Optics

The Fiber Unit Quick Selection Guide from Keyence Corp. of America, Woodcliff Lake, NJ, describes fiber optic units for sensing applications. Products include conventional and flexible fibers, lens attachments, thru beams, area detection fibers, liquid level detectors, and amplifiers. **Circle No. 717**

Motion and Vision Systems

Data Science Automation, Canonsburg, PA, offers a 40-page catalog describing motion and vision system components, systems, and integration services. The catalog includes system design; engineering services and training; and component descriptions of software, frame grabbers, cables, cameras, lenses, lighting, and fixtures for complete vision systems. **Circle No. 718**

Magnetic Measuring

Walker Scientific, Worcester, MA, offers a brochure highlighting magnetic measuring and analysis instrumentation, electromagnet systems, regulated power supplies, magnetizing and conditioning equipment, and alloy classification and identification equipment. Products include gaussmeters, fluxmeters, magnetometers, hysteresisgraphs, magnet charger and conditioners, laboratory electromagnets, solenoids, and helmholtz coils. **Circle No. 719**

Calibration and Control

The BigCat 2000 Master Catalog from TRANSCAT, Rochester, NY, features more than 8,000 products for calibration, electrical, electronic, test, measurement, and control. Also included are the company's ISO 9002 Registered and ISO/IEC Guide 25 accredited Certified Calibration and Repair Services, and M3-Meter Master Modification Manufacturing. The catalog features pressure, temperature, and electronic calibration devices. **Circle No. 720**

Spring-Energized Seals

Ultra Seal, Rancho Cucamonga, CA, offers an eight-page catalog of seals energized by a corrosion-resistant spring. The seals are manufactured from low-friction PTFE and UHMW PE compounds. Standard and custom sizes are available in metric and English units. Operating range, seal designs, service, applications, markets, and general information on energized seals are included. **Circle No. 721**

Positioning Systems

Aerotech, Pittsburgh, PA, offers a 400-page catalog on positioning systems and motion control products. Included are air bearing stages, linear motor stages, linear motor gantry systems, linear and rotary stages, interferometers, motion controllers, drives, and linear and rotary motors. **Circle No. 722**

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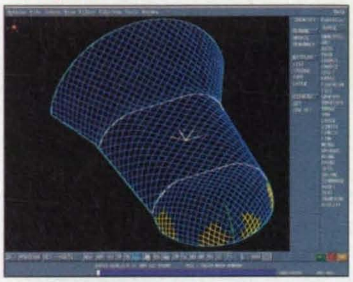
Simulation Cuts 400 Hours from Time Required to Prototype Fighter-Aircraft Component



Engineers at the Lockheed Martin Skunkworks found that computer simulation reduced the time required to prototype a typical composite component for the Joint Strike Fighter (JSF) from 750 to 350 hours. FiberSIM, a simulation tool from Composite Design Technologies, Waltham, MA, allowed the engineers to troubleshoot the ply design on the computer, so that the physical plies could be laid-up without delay. The program was then used to drive an automated ply cutter and laser projection system, which provided further time savings. Lockheed has used this method to prototype more than 80 composite parts for the JSF — without requiring any rework due to ply-geometry issues.

www.rapidproducts.net/Sept00/simulation900.html

New Product Highlights

Prodigy, from Stratasys, Eden Prairie, MN, is a compact Fused Deposition Modeling (FDM) system. It enables designers to test form, fit, and function with durable ABS parts produced within a networked office environment. The machine measures 34 x 27 x 41" and has a build envelope of 8 x 8 x 12". A front display panel prompts the user through the steps required to begin building a part.

www.rapidproducts.net/Sept00/products900.html

Industrial Design Firm Uses Gantry Router to Reduce Prototype Costs

Anderson Design is a general-purpose, industrial-design house with clients in industries ranging from toys to heavy machinery. Preparing prototype models for client review is a critical part of the company's product development process, and this prototyping had been done by hand using urethane foam. Then the company purchased a gantry router from Techno-Isel, New Hyde Park, NY. This machine, which costs significantly less than an SLA or CNC system, has resulted in shorter design cycles, faster turnaround, lower costs, and the ability to evaluate more design options.

www.rapidproducts.net/Sept00/gantry900.html

Mastering the Transition from 2D to 3D Design

Eclipse Combustion, a manufacturer of burner and combustion equipment and systems, recently made the transition from 2D to 3D design, standardizing on AutoCAD-based technology. In its search for a viable design solution, the company's greatest challenge was to find a package offering full 2D and 3D capabilities, availability of viable CAM solutions, and AutoCAD format capability. Eclipse enlisted the help of Avatech Solutions, Owings Mills, MD, to design and implement a complete migration program. This structured approach resulted in a smooth transition to 3D, with improved productivity and a significant reduction in errors and redundancies.

www.rapidproducts.net/Sept00/transition900.html

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